Ministry of
Northern Development
and Mines
Ontario

Mines and
Minerals
Division

Geology of

Carbonatite – Alkalic Rock Complexes in Ontario:

# Firesand River Carbonatite Complex

District of Algoma

Ontario Geological Survey
Study 47

by R. P. Sage

1988

© 1988 Queen's Printer for Ontario
ISSN 0704–2590
Printed in Ontario, Canada
ISBN 0–7729–0582–7

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**Canadian Cataloguing in Publication Data**

Sage, R. P.

Geology of carbonatite–alkalic rock complexes in Ontario : Firesand River carbonatite complex, district of Algoma

(Ontario Geological Survey study, ISSN 0704–2590 ; 47)

Includes index.

ISBN 0–7729–0582–7

1. Carbonatites—Ontario—Firesand River. 2. Alkalic igneous rocks—Ontario—Firesand River. I. Ontario. Ministry of Northern Development and Mines. II. Ontario Geological Survey. III. Title. IV. Series.

QE461.S23 1988 552'.1'09713132 C88–099664–1

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Parts of this publication may be quoted if credit is given. It is recommended that reference to this report be made in the following form:

Sage, R.P.
1988: Geology of Carbonatite – Alkalic Rock Complexes in Ontario: Firesand River Carbonatite Complex, District of Algoma; Ontario Geological Survey, Study 47, 82p.

1000–88–Lowe–Martin Co. Inc.

# Foreword

The Firesand River Carbonatite Complex was examined as part of a project to study alkalic rock – carbonatite complexes in Ontario. The study describes the rock types and mineralogy of the complex and outlines the history of the mineral exploration efforts within the complex.

V.G. Milne

*Director*
*Ontario Geological Survey*

# Contents


Abstract ..... 2
Résumé ..... 2
Introduction ..... 3
Acknowledgments ..... 3
Location And Access ..... 3
Field Methods ..... 3
Previous Geological Work ..... 5
Physiography ..... 5
Laboratory Technique ..... 5
Nomenclature ..... 5
General Geology ..... 7
Early Precambrian (Archean) ..... 9
Metavolcanics ..... 9
Intermediate To Mafic Metavolcanics ..... 9
Intermediate To Felsic Metavolcanics ..... 9
Felsic Intrusive Rocks (Quartz–feldspar Porphyry) ..... 10
Late Precambrian (Proterozoic) ..... 12
Diabase Dikes ..... 12
Firesand River Carbonatite Complex ..... 12
Sovite And Silicocarbonatite Rim Rocks ..... 12
Sovite ..... 12
Ferruginous Sovite ..... 16
Silicocarbonatite To Ijolite ..... 17
Ijolite ..... 24
Biotitite ..... 25
Rauhaugite Core Rocks ..... 25
Ferruginous Dolomite ..... 25
Barite–quartz Phase ..... 26
Dike Rocks ..... 27
Sovite Dikes ..... 27
Silicocarbonatite Dikes ..... 27
Lamprophyre Dikes ..... 27
Ferruginous Carbonate ..... 28
Petrology ..... 28
Metamorphism ..... 29
Structural Geology ..... 30
Regional Setting ..... 30
Internal Structures ..... 31
Magnetic Response And Radioactivity ..... 31
Recommendations For Future Study ..... 31
Economic Geology ..... 33
Property Descriptions ..... 33
Algoma Steel Corporation Limited ..... 33
Gibson Property ..... 34
International Minerals And Chemical Corporation ..... 35
Morrison et al. Claims ..... 35
Pango Gold Mines Limited ..... 36
Recommendations To The Prospector ..... 36

Appendix A — Petrographic Descriptions, Chemical Analyses, Normative Compositions, And Statistical Compositions Of Lithologic Units .... 37
References .... 77
Index .... 79

**FIGURES**

1. Key Map .... 4
2. Aeromagnetic Map Of The Firesand River Carbonatite Complex ... 8
3. Geology Of The Firesand River Complex .... Chart A
4. Main Pyrochlore Showing On Morrison et al. Claims .... 35

**TABLES**

1. Table Of Lithologic Units .... 7
2. Microprobe Analyses Of Iron–titanium Oxides .... 14
3. Microprobe Analyses Of Carbonates .... 15
4. Microprobe Analyses Of Olivine And Monticellite .... 16
5. Microprobe Analyses Of Garnets .... 17
6. Microprobe Analyses Of Pyroxenes .... 19
7. Microprobe Analyses Of Micas .... 20
8. Microprobe Analyses Of Amphiboles .... 22
9. Drilling Completed On The Firesand River Complex, 1951–1976. 33
10. Iron Assays For Samples From The Gibson Property .... 35
A–1. Petrographic And Field Descriptions Of Whole–rock Samples .. 37
A–2. Major Element Analyses Of Whole–rock Samples .... 51
A–3. Trace Element Analyses Of Whole–rock Samples .... 56
A–4. Normative Minerals For Whole–rock Samples .... 66
A–5. Average Chemical Compositions Of Lithologic Units .... 76

**CHART (back pocket)**

Chart A (coloured) — Figure 3.

## CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

| Conversion from SI to Imperial | | | Conversion from Imperial to SI | | |
|---|---|---|---|---|---|
| *SI Unit* | *Multiplied by* | *Gives* | *Imperial Unit* | *Multiplied by* | *Gives* |
| | | LENGTH | | | |
| 1 mm | 0.039 37 | inches | 1 inch | **25.4** | mm |
| 1 cm | 0.393 70 | inches | 1 inch | **2.54** | cm |
| 1 m | 3.280 84 | feet | 1 foot | **0.304 8** | m |
| 1 m | 0.049 709 7 | chains | 1 chain | 20.116 8 | m |
| 1 km | 0.621 371 | miles (statute) | 1 mile (statute) | **1.609 344** | km |
| | | AREA | | | |
| 1 $cm^2$ | 0.155 0 | square inches | 1 square inch | **6.451 6** | $cm^2$ |
| 1 $m^2$ | 10.763 9 | square feet | 1 square foot | **0.092 903 04** | $m^2$ |
| 1 $km^2$ | 0.386 10 | square miles | 1 square mile | 2.589 988 | $km^2$ |
| 1 ha | 2.471 054 | acres | 1 acre | 0.404 685 6 | ha |
| | | VOLUME | | | |
| 1 $cm^3$ | 0.061 02 | cubic inches | 1 cubic inch | **16.387 064** | $cm^3$ |
| 1 $m^3$ | 35.314 7 | cubic feet | 1 cubic foot | 0.028 316 85 | $m^3$ |
| 1 $m^3$ | 1.308 0 | cubic yards | 1 cubic yard | 0.764 555 | $m^3$ |
| | | CAPACITY | | | |
| 1 L | 1.759 755 | pints | 1 pint | 0.568 261 | L |
| 1 L | 0.879 877 | quarts | 1 quart | 1.136 522 | L |
| 1 L | 0.219 969 | gallons | 1 gallon | **4.546 090** | L |
| | | MASS | | | |
| 1 g | 0.035 273 96 | ounces (avdp) | 1 ounce (avdp) | 28.349 523 | g |
| 1 g | 0.032 150 75 | ounces (troy) | 1 ounce (troy) | **31.103 476 8** | g |
| 1 kg | 2.204 62 | pounds (avdp) | 1 pound (avdp) | **0.453 592 37** | kg |
| 1 kg | 0.001 102 3 | tons (short) | 1 ton (short) | **907.184 74** | kg |
| 1 t | 1.102 311 | tons (short) | 1 ton (short) | **0.907 184 74** | t |
| 1 kg | 0.000 984 21 | tons (long) | 1 ton (long) | **1016.046 908 8** | kg |
| 1 t | 0.984 206 5 | tons (long) | 1 ton (long) | **1.016 046 908 8** | t |
| | | CONCENTRATION | | | |
| 1 g/t | 0.029 166 6 | ounce (troy)/ ton (short) | 1 ounce (troy)/ ton (short) | 34.285 714 2 | g/t |
| 1 g/t | 0.583 333 33 | pennyweights/ ton (short) | 1 pennyweight/ ton (short) | 1.714 285 7 | g/t |

### OTHER USEFUL CONVERSION FACTORS

| | | |
|---|---|---|
| 1 ounce (troy) per ton (short) | 20.0 | pennyweights per ton (short) |
| 1 pennyweight per ton (short) | 0.05 | ounces (troy) per ton (short) |

*Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in cooperation with the Coal Association of Canada.*

# Geology of
# Carbonatite – Alkalic Rock Complexes in Ontario:
# Firesand River Carbonatite Complex
## District of Algoma

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1. Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto. Manuscript approved for publication by John Wood, Chief Geologist, Ontario Geological Survey, October 26, 1983.

This report is published with the permission of V.G. Milne, Director, Ontario Geological Survey.

# Abstract

The Firesand River Carbonatite Complex lies within the Wawa Subprovince, immediately north of the Kapuskasing Subprovince of the Superior Province of the Canadian Shield. The emplacement of the intrusion was likely controlled by the extension of faults and fractures of the Kapuskasing Subprovince.

The complex consists of sovite, silicocarbonatite, ijolite, rauhaugite, and various dike rocks. The carbonatite intrusion is zoned from a calcitic rim to a ferruginous dolomite core. The rocks of the complex have yielded dates of 1008 and 1087 Ma by K–Ar isotopic techniques.

The complex has been examined for its niobium content, tested for residual apatite deposits, and examined as a potential source of calcite for the local sinter plant of Algoma Steel Corporation Limited. By analogy with rare–earth–rich, dolomitic core rocks found within the St. Honôré carbonatite, Québec, the dolomitic core of the Firesand River Carbonatite Complex should be tested for its rare earth element content.



# Résumé

Le complexe de carbonatite de la rivière Firesand est situé dans la sous–province de Wawa, au nord de la sous–province de Kapuskasing, dans la province Supérieure du bouclier canadien. Il semble que l'emplacement de l'intrusion résulte de l'extension des failles et des fractures de la sous–province de Kapuskasing.

Le complexe est formé de sovite, de silicocarbonatite, d'ijolite, de rauhaugite, et de divers dykes. L'intrusion de carbonatite est délimitée par une enveloppe de calcaire et un noyau de dolomite ferrugineuse. D'après les techniques isotopiques de datation au K–Ar, l'âge des roches du complexe est de 1008 à 1087 Ma.

On a évalué la teneur du complexe en niobium, recherché la présence de gîtes résiduels d'apatite et déterminé si le complexe contenait suffisamment de calcite pour l'exploitation de tuf d'Algoma Steel Corporation Limited. Tout comme on a fait pour les carottes dolomitiques riches en terres rares prélevées dans la carbonatite de St–Honoré (Québec), on devrait déterminer la teneur en terre rare des carottes dolomitiques du complexe de carbonatite de la rivière Firesand.



Geology of Carbonatite – Alkalic Rock Complexes in Ontario: Firesand River Carbonatite Complex, District of Algoma, by R.P. Sage. Ontario Geological Survey, Study 47, 82p. Published 1988. ISBN 0–7729–0582–7.

# Introduction

As part of a study of alkalic rock – carbonatite complexes, the Firesand River Carbonatite Complex, originally mapped by Parsons (1961), was remapped to update outcrop data, rock chemistry, and exploration activity on the body.

The carbonatite lies within the supracrustal rocks of the Wawa greenstone belt of the Wawa portion of the Abitibi Subprovince of the Superior Province of the Canadian Shield. This supracrustal sequence lies along the west side of the Kapuskasing Subprovince.

The carbonatite complex is slightly elliptical in plan view, being elongate in a northeast direction. The outer rim of the complex consists of a mixed sequence of sovite and silicocarbonatite. The core of the complex consists of ferruginous dolomite.

The silicocarbonatite of the rim consists of highly altered xenolithic inclusions, cumulate phases and ijolite containing carbonate and biotite. The carbonatite is enclosed by brecciated and fenitized metavolcanic and intrusive rocks. Ferruginous carbonate dikes, commonly radioactive, that cut the supracrustal rocks of the Wawa greenstone belt probably are of the same or similar age as the carbonatite intrusion.

The complex has been prospected for iron, niobium, apatite, and calcite. Minor quantities of uranium are known to be present.


### Acknowledgments

The complex was originally mapped by Parsons (1961), and his report and map were invaluable aids to the present project. Parsons' report and map are now out of print, and some material from his report, particularly concerning economic geology, has been incorporated in the present report. Parsons' map was used as a base map for this project, and has been modified based on field mapping, petrographic study, and chemical analysis.

The author was assisted in mapping the complex by Mr. Ron Case of Wawa, Ontario.

Mr. J. Huddart, Algoma Steel Corporation, presented to the Ministry the records resulting from exploration work on the complex completed by the company. Dr. George Erdosh of the International Minerals and Chemical Corporation discussed the results of the work completed by this company on the body.

Ms. S. Teal discussed the results of her M.Sc. studies on the complex with the author. Her microprobe analyses of the mineral phases of silicocarbonatite are reproduced in this report.


### Location and Access

The Firesand River complex (Figure 1) is located approximately 7 km east of Wawa and lies on the common boundary of McMurray and Lastheels Townships. Access is by a rough road extending south from Highway 101 along the west bank of the Firesand River. The complex lies approximately 3 km south of Highway 101. The surface area of the complex is approximately 4.5 km$^2$ as indicated by aeromagnetic maps 2191G and 2192G (ODM–GSC 1963a,b) (see Figure 2).

### Field Methods

A grid cut by Algoma Steel Corporation during their exploration program was not completely usable at the time of the author's work. Sections of the baselines

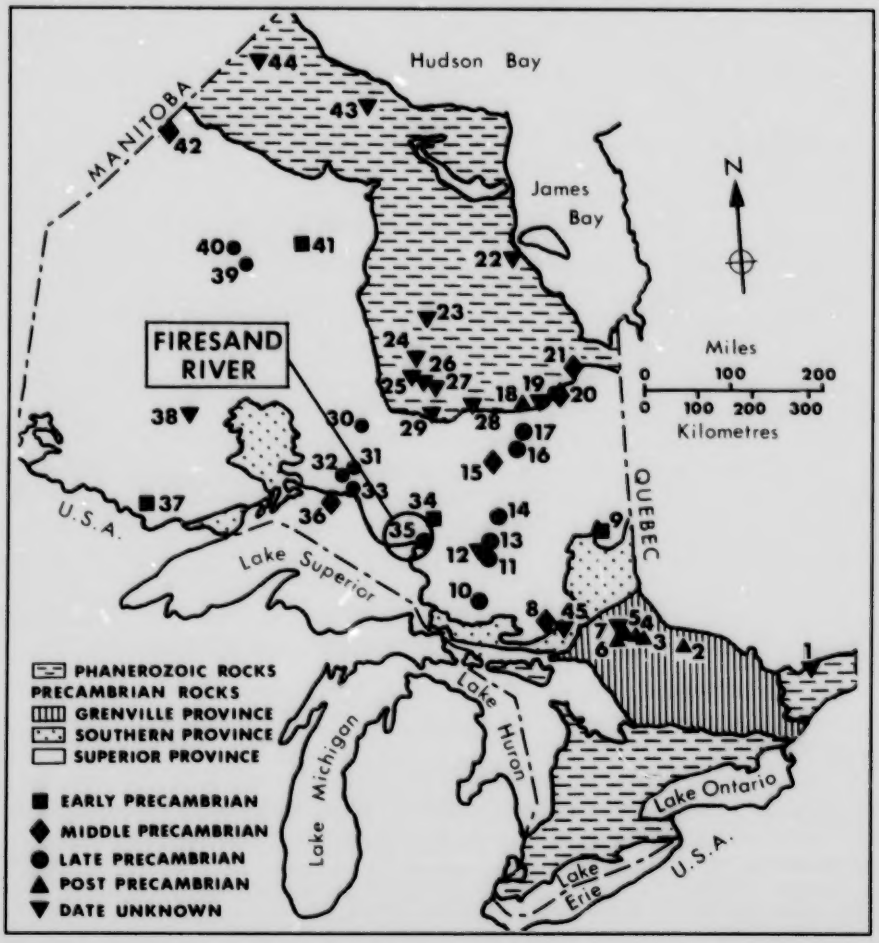


**Figure 1.** *Key map showing location of carbonatite - alkalic rock complexes in Ontario.*

1. *Eastview*
2. *Brent*
3. *Callander B.*
4. *Manitou Is.*
5. *Burritt Is.*
6. *Iron Is.*
7. *Lavergne*
8. *Spanish R.*
9. *Otto Stock*
10. *Seabrook L.*
11. *Lackner L.*
12. *Borden Tp.*
13. *Nemegosenda L.*
14. *Shenango Tp.*
15. *Cargill Tp.*
16. *Teetzel Tp.*
17. *Clay-Howells*
18. *Hecla-Kilmer*
19. *Valentine Tp.*
20. *Goldray*
21. *Argor*
22. *Lawashi R.*
23. *Poplar R.*
24. *Albany Forks*
25. *L. Drowning R.*
26. *Kingfisher R. West*
27. *Kingfisher R. East*
28. *Martison L.*
29. *Nagagami R.*
30. *Chipman L. (dikes)*
31. *Killala L.*
32. *Prairie L.*
33. *Port Coldwell*
34. *Herman L.*
35. **Firesand R.**
36. *Slate Is.*
37. *Poohbah L.*
38. *Sturgeon Narrows & Squaw L.*
39. *Schryburt L.*
40. *Big Beaver House*
41. *Wapikopa L.*
42. *"Carb" L.*
43. *Gooseberry Br.*
44. *Niskibi L.*
45. *Nemag L. & Lusk L.*

could be traced and portions of the baselines were used for control. Mapping was by pace and compass along ridges, lakeshores and stream valleys. Outcrop, where present, tends to occur on the sides of gulleys and ridges. Outcrop data was plotted on acetate overlays of 1:15,840 scale airphotos provided by the Air Photo Library of the Ontario Ministry of Natural Resources. The base map was an enlargement of the map prepared by Parsons (1961). Data from acetate overlays, Parsons (1961) map, and exploration data were plotted on blank acetate at a scale of 1:7920.

### Previous Geological Work

The first mention of mineralization at the Firesand River Carbonatite Complex appeared in the Canadian Mining Journal in 1924. The reported mineralization was hematite, formed by weathering of the ferruginous dolomite core of the complex. Collins and Quirke (1926) described early exploration efforts. Parsons (1961) report covered most of the essential features of the geology of the complex.

Heinrich and Vian (1967) published a brief paper on barite–quartz mineralization at the complex. Kahn (1972 a,b) prepared reports for Algoma Steel Corporation Limited on the feasibility of using calcite in the sinter plant in Wawa. Erdosh (1976) prepared a report for the International Minerals and Chemical Corporation concerning the search for residual apatite accumulations.

The author prepared a brief summary of the geology of the complex as part of Operation Chapleau (Thurston *et al.* 1977). Teal (1979), from McMaster University, completed a M.Sc. study on the complex.

### Physiography

The eastern portion of the complex is covered by sand plains west of the Firesand River and the western portion of the complex consists of rolling hills with topographic relief on the order of 25 m.

The complex is covered with thick bush and outcrop is scarce, nonetheless, the Firesand River Carbonatite Complex is probably the best exposed carbonatite complex in Ontario. All outcrop lies outside the area of sand plain and within the western half of the intrusion.

### Laboratory Technique

A selected suite of samples were thin sectioned for petrographic examination and those representative of homogeneous outcrops or homogeneous core lengths from the 1972 drilling by the Algoma Steel Corporation were submitted for complete chemical analysis. The core from all previous drilling before 1972 has been destroyed.

### Nomenclature

For the alkalic rocks, the author prefers to use mineralogic, colour, or textural modifiers, which are familiar to all readers, rather than unfamiliar rock names. Alkalic rock nomenclature is cumbersome, due in large part to the profusion of unfamiliar rock names. Consequently, as an aid to the reader, the use of less familiar rock names will be limited. The rock terms retained by the author and the way they are used are given below.

*Ijolite*. A nepheline–pyroxene rock with a nepheline content between 30 and 70 percent. Rocks containing more than 70 percent nepheline are classified as

urtite and those with less than 30 percent as melteigite. Some specimens may contain significant amounts of biotite in place of pyroxene. Potassium feldspar content is 10 percent or less and those rocks with 10 percent or less nepheline are classified as pyroxenite.

*Malignite*. A melanocratic nepheline syenite. In general, nepheline, pyroxene and potassium feldspar occur in roughly equal proportions. The potassium feldspar content must exceed 10 percent or the rock is classified as belonging to the ijolite suite. Both the nepheline and pyroxene content must exceed 10 percent or the rock would be classified with the syenites. This rock group is transitional between the ijolites and overlaps the syenitic rock groups.

*Sovite*. A carbonatite rock composed of 50 percent or more calcite. Various mineralogic modifiers are used to classify the sovite, for example, apatite–magnetite sovite, olivine–amphibole sovite, etc.

*Silicocarbonatite*. A carbonatite rock containing 50 percent or more oxide and silicate minerals. Where the silicate or oxide mineralogy exceeds 90 percent various other rock names are applied; i.e. ijolite, biotite, pyroxenite, etc.

*Syenite*. This term is restricted to a quartz–free rock consisting primarily of alkali feldspars. Various mafic minerals and nepheline may be present and form a significant component of the rock. The syenites are named on the basis of their mineralogy, i.e., pyroxene–nepheline syenite, biotite–amphibole syenite, etc. The syenites are gradational into malignites.

There is no standard subdivision of the ijolite suite into ijolite, urtite, and melteigite. Bailey (1974) classified urtites as having more than 70 percent nepheline, however he uses the term ijolite to apply only to those rocks containing between 50 and 70 percent nepheline. The author finds this range to be too restricted for field use and prefers the 30 to 70 percent range given by Williams *et al.* (1954, p.70).

Malignite from the Poohbah Lake Complex in northwestern Ontario was originally defined by Lawson (1896) as an alkali–rich rock containing pyroxene, and potassium feldspar, with or without nepheline, garnet and amphibole. The author has examined the malignite of this complex in the field and in a large number of thin sections. The malignites are melanocratic and contain pyroxene, nepheline, orthoclase, garnet, and amphibole. The nepheline content of the type location is relatively low compared with the definition given above. For field work and to better emphasize the gradational nature of malignite into ijolites and syenites without the use of cumbersome terminology, a broader usage of the term has been applied by the author. Williams *et al.* (1954, p.65–66)described a number of malignites of varying mineralogy.

The Poohbah Lake type location for malignite was re–investigated by Mitchell and Platt (1978) and malignite was redefined by them as a nepheline syenite containing oikocrystic potassium feldspar. The author considers the definition of Mitchell and Platt too restrictive. In this report, the term malignite is used, as defined by Sorensen (1974, p.27), for a melanocratic nepheline syenite.

The definitions of sovite and silicocarbonatite are modified from Heinrich (1966, p.12). The author has found Heinrich's subdivision of the carbonate–rich carbonatitic rocks generally suitable for field usage when modified to a two–fold subdivision at about 50 percent oxide and silicate mineral contents. The two–fold subdivision is more convenient than the four–fold subdivision of Heinrich (1966) because carbonatites show extreme variations in mineral content over distances of less than a few centimetres. It is difficult to rigorously classify such heterogeneous rocks.

# General Geology

The Firesand River Carbonatite Complex (Table 1, Figure 2 and Figure 3, Chart A) lies within an east–trending belt of Archean supracrustal rocks and associated subvolcanic intrusions. The rocks bordering the complex are brecciated and fenitized. The complex consists almost exclusively of carbonatite rocks and ijolite. Nepheline syenite is absent. The complex is known to host niobium, uranium, and phosphorus mineralization. Gittins *et al.* (1967) reported K–Ar isotopic ages on biotite of 1008 and 1087 Ma for the complex.

The complex was previously mapped by Parsons (1961) and the general distribution of rock types as outlined by him was not changed by the present survey. The complex is probably more elongate in a northeast–southwest direction than previously indicated. Mapping into the wall rocks by the author for distances up

**TABLE 1. TABLE OF LITHOLOGIC UNITS FOR THE FIRESAND RIVER CARBONATITE COMPLEX.**

**CENOZOIC**

**Recent**
Stream, swamp, and river deposits.

**Pleistocene**
Glacial deposits, boulders, gravel, sand, silt.

*Unconformity*

**LATE PRECAMBRIAN (PROTEROZOIC)**

**Firesand River Carbonatite Complex**

**Dike Rocks**
Sovite, silicocarbonatite, lamprophyre, ferruginous carbonate.

*Intrusive Contact*

**Rauhaugite Core Rocks**
Ferruginous dolomite.

*Intrusive and Gradational Contact*

**Sovite and Silicocarbonatite Rim Rocks**
Sovite, ferruginous sovite, silicocarbonatite, ijolite, biotitite, xenoliths of metavolcanics.

*Intrusive Contact*

**Diabase Dikes**
Diabase.

*Intrusive Contact*

**EARLY PRECAMBRIAN (ARCHEAN)**

**Felsic Intrusive Rocks**
Feldspar porphyry, quartz–feldspar porphyry, commonly fenitized along joint planes.

*Intrusive Contact*

**Metavolcanics**

**Intermediate to Felsic Metavolcanics**
Flows, tuff, porphyritic flows, commonly fenitized along joint planes.

**Intermediate to Mafic Metavolcanics**
Flows, commonly fenitized along joint planes.

to 1000 m disclosed fenitization and carbonatite diking. Rusty-weathering carbonatite dikes were noted in road cuts along Highway 101 several kilometres north of the complex. The width of the fenetic halo around the complex is unknown. Carbonatite-lamprophyre dikes found some distance from the complex are probably related to the same magmatic event.

Miarolitic cavities in the carbonate rocks within the core of the complex imply that the present level of exposure is relatively high. The complex consists of a dolomite-rich core and a calcite-rich rim (Parsons 1961). Examination by the author of diamond drill core from Algoma Steel Corporation's 1972 drilling indicated that the calcitic rim consists of a complex mixture of carbonate (sovite), silicocarbonatite, ijolite, and wall rock fragments derived from the enclosing supracrustal sequence. The wall rock fragments are altered to varying degrees by the development of dark green pyroxene and/or amphibole and biotite. At surface the carbonatite rim consists of medium- to coarse-grained, white to pink

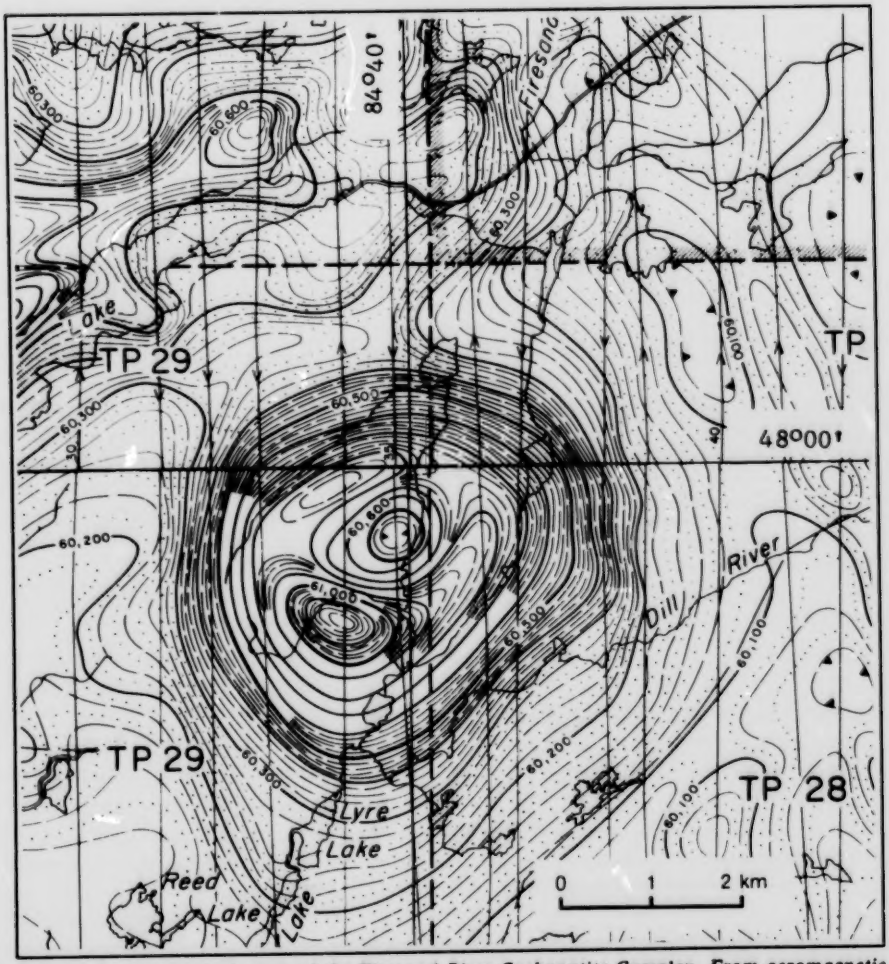


**Figure 2.** *Aeromagnetic map of the Firesand River Carbonatite Complex. From aeromagnetic maps 2191G, 2192G (ODM-GSC 1963a,b).*

carbonate. The pink coloured varieties are richer in iron and often display a thin limonitic coating.

The dolomitic core consists of a fine–grained buff carbonatite (rauhaugite) with a thick hematite and/or goethite coating. Fresh rock from the core area was rarely found. Several specimens of coarse barite and quartz were found in slump or float during mapping of the complex. This quartz–barite mixture may occur in fractures within the dolomitic core of the body.

Banding within the carbonatite is vertical to subvertical and crudely conforms to the outline of the body even though relatively large variations in foliation trends may occur between closely spaced outcrops.

## EARLY PRECAMBRIAN (ARCHEAN)

The Firesand River Carbonatite Complex is completely enclosed within Archean supracrustal rocks of the Michipicoten greenstone belt of the Wawa Subprovince of the Superior Province of the Canadian Shield.

### METAVOLCANICS

#### Intermediate To Mafic Metavolcanics

Intermediate to mafic metavolcanics (unit 1) were encountered west and south of the Firesand River Carbonatite Complex. The rocks are massive and lack any visual evidence of primary structures. The rocks are fine grained and both chlorite– and hornblende–bearing varieties were encountered. The rocks appear to have been metamorphosed to the upper greenschist or lower amphibolite facies rank of regional metamorphism and all outcrops examined had been fenitized to varying degrees by fluids derived from the carbonatite intrusion.

Along the creek bed on the west flank of the complex, the mafic to intermediate metavolcanics are veined with silicocarbonatite dikes. Fractures within the rock are coated with biotite and white carbonate marginal to the larger carbonatite dikes. The mafic metavolcanics display a selvage of variable width of fine– to coarse–grained biotite.

One sample of altered mafic metavolcanics was collected from location "B" (Figure 3, Chart A) and examined in thin section. The rock is a mixture of very fine–grained, prismatic, pale–green to colourless amphibole and saussurite (?).

While green pyroxene or amphibole have developed in the mafic rocks, biotite appears to have developed preferentially to either pyroxene or amphibole. In contrast, amphibole or pyroxene are preferentially developed in rocks of felsic composition.

#### Intermediate To Felsic Metavolcanics

Intermediate to felsic metavolcanics (unit 2) occur dominantly on the northwest flank of the complex. These rocks are massive, flow banded and porphyritic flows, or oligomictic lapilli tuffs. The best exposure occurs at the beaver dam at the north end of Blasko Lake.

The flow banded units display a convoluted streaky pattern wherein individual bands are of variable width but generally about a millimetre. The bands are generally shades of grey in colour.

The tuffs are oligomictic even though an occasional accidental fragment may be present. Angular to subangular fragments up to 3 to 4 cm in maximum dimen-

sion were noted, and several exposures display fragments having reaction rims up to 2 and 3 mm wide. The rims are buff in colour in contrast to grey to blue–grey cores. The flow banded and tuffaceous units are intimately mixed.

Several outcrops of felsic rocks containing small 1 to 2 mm quartz and feldspar phenocrysts are thought to be extrusive phases of the quartz–feldspar porphyry rocks. These rocks could also be dikes or a chilled contact facies of the larger quartz–feldspar intrusive body, but the lack of field data prevents precise classification. The descriptions of quartz–feldspar porphyry (unit 3) also apply to this rock unit.

On weathered surface the felsic rocks weather grey, blue–grey to green–grey and on fresh surface they are the same colours but with generally darker tints. No fresh unfenitized outcrop of this map unit was observed. Fractures are lined with dark green pyroxene or amphibole, and the centre of the fracture often contains carbonate (commonly ferruginous) and scattered grains of biotite. Closer to the carbonatite–felsic metavolcanic contact, the fracturing and metasomatic alteration becomes increasingly pronounced to the point where it imparts a brecciated appearance to the outcrop wherein angular clasts of less altered rock are separated by a dark green matrix.

In thin section the felsic metavolcanics are fine grained, massive, equigranular, allotriomorphic, granoblastic with curved to lobate grain boundaries. The mode is highly variable: 25 to 30% of the rock is pyroxene and the remainder is a mosaic of fine–grained quartz and sodic(?) plagioclase. Biotite, carbonate, epidote, and magnetite are present in one or more samples.

The pyroxene is a green to dark green, sometimes turbid, elongate to acicular aegirine augite. The pyroxene occurs intergranular to the feldspars and quartz and along fractures traversing the rocks. Where biotite and carbonate are present they are generally centrally located within the pyroxene–filled fractures.

The matrix to the clinopyroxene is granoblastic and undoubtedly resulted from a thermal–metasomatic (contact metamorphic) overprint of a regionally metamorphosed rock. Quartz was visually identified in one specimen but optically the matrix is generally too fine grained to easily identify the individual minerals. The quartz–feldspar grain boundaries are curved to lobate and interlock. The feldspar in one sample was identified as a braided perthite.

Several outcrops of very fine–grained metavolcanics of intermediate to felsic composition were mapped along the southern flank of the complex but were not examined in thin section. These exposures are buff, green–buff, to grey weathering and similar colours of darker tints prevail on the fresh surface.

## FELSIC INTRUSIVE ROCKS (QUARTZ–FELDSPAR PORPHYRY)

Quartz–feldspar porphyry is common along the southern flank of the complex and has limited exposure on the north flank. This unit is likely one intrusive unit that has been dismembered by the emplacement of the Firesand River Carbonatite Complex. Parsons (1961) mapped the unit as granite, however the author interprets the unit to be a typical subvolcanic, porphyritic intrusion that is common within most supracrustal belts.

The best exposures of this unit are located on the southern flank. Quartz is not visible in the rock within a zone extending 540–600 m from the carbonatite–porphyry contact. While the feldspar porphyry may be a distinct primary phase of the intrusion, the author interprets the feldspar porphyry to be the result of removal of quartz during fenitization. Desilication is a characteristic feature of the

fenitization process and the feldspar porphyry occurs in the area of greatest fenitization proximal to the carbonatite intrusion. Pyroxene or amphibole–rimmed quartz phenocrysts were noted and selective and complete replacement of the quartz by pyroxene or amphibole can be easily seen in a number of exposures. The feldspars within the more strongly fenitized rock are chalky and dull in appearance and have been extensively altered. In the more altered rocks, a slightly pitted weathered surface has developed by the preferential weathering of the altered feldspar crystals.

The quartz and feldspar phenocrysts may approach 8 mm in diameter but generally are 5 mm or less. The phenocrysts are seriate in distribution and fade into the groundmass. On the outcrop the quartz phenocrysts are rounded and the feldspars are euhedral and elongate. Differential weathering of the feldspar phenocrysts suggests some primary compositional zoning of the crystals. Quartz phenocrysts rarely exceed an estimated 10% of the rock but the feldspar phenocrysts may approach 40 to 45%.

Fractures within this unit are dark green from the development of pyroxene or amphibole and as the contact area is approached become so pervasive as to impart a brecciated pattern to the outcrop. Within the wider fractures or areas of more intense alteration, the centres of some fractures contain carbonate and some biotite.

The relatively fresh rock is buff, grey to green–grey on weathered surface. The buff to chalky white feldspars commonly impart a mottled colouring to the rock. Similar colouring exists on the fresh surface but generally with a slightly darker tint. On fresh surfaces the quartz phenocrysts are clear and glassy.

In thin section the quartz–feldspar porphyry is fine to medium grained, inequigranular–porphyritic–seriate, allotriomorphic, granoblastic with curved to lobate grain boundaries.

Rocks of this unit have highly varied modes, mainly because of the process of fenitization. The mode of the porphyritic rock is estimated to be 0 to 25% quartz phenocrysts, 30 to 45% feldspar phenocrysts, 10 to 25% pyroxene, and 30 to 70% very fine–grained quartz–feldspar groundmass. Carbonate and biotite are present in one or more samples and about 10% microcline is present in one sample.

The quartz phenocrysts consist of polycrystalline aggregates with wavy extinction. The external grain boundaries are cuspate to lobate to the enclosing matrix. Internally the individual grains have curved grain boundaries. Fractures within the quartz may be occupied by green pyroxene and minor carbonate.

The plagioclase consists of anhedral to subhedral grains, some of which are composite in nature. The composite appearance is, in some cases, likely due to metamorphic breakdown of the original phenocryst, while in other instances the grains represent glomeroporphyritic growth. The feldspars are locally turbid, extensively saussuritized, and have ragged grain boundaries. The core areas are commonly more intensely altered than the rims. The sericitic alteration occurs in two orientations at 90° to each other, implying structural (cleavage) control of the alteration. Completely fresh phenocrysts are rare but unaltered patches remain which can be studied optically. Rare bending of relict albite (010) twin planes was observed and Carlsbad twinning is present in one sample.

Fresh or relatively clear patch and string perthites are likely the result of recrystallization accompanying metasomatism and metamorphism of the rock. In one sample, perthite forms large, optically continuous, poikiloblastic grains

dusted with tiny inclusions of aegirine augite. The perthite encloses angular to subangular grains of plagioclase and a perthite similar in appearance to the host.

The feldspar grains have serrate margins contacting the finer-grained matrix as well as internally serrate contacts with the enclosed inclusions.

On the basis of limited data the phenocrysts range from albite to oligoclase in composition. Metasomatism has undoubtedly altered or modified their original composition towards a more sodic end member.

The clinopyroxene is a green to dark green aegirine augite. The crystals are elongated to acicular and may be scattered throughout a sample but generally form aggregates of several grains.

The pyroxene displays a marked preference to occur along the margins of quartz grains and along fractures.

The groundmass is very fine grained, granoblastic with lobate to serrate grain boundaries. Sericite after feldspar is common within the groundmass and may form a dominant phase of the sample. The sericite grains appear to be oriented subparallel to each other and therefore impart a microscopic schistosity to the sample.

## LATE PRECAMBRIAN (PROTEROZOIC)

Diabase dikes sharply cut the Early Precambrian supracrustal rocks on the south flank of the intrusion and are truncated by rocks of the complex. The precise age of the dikes is unknown and their classification as Late Precambrian is arbitrary.

### DIABASE DIKES

Two slumped exposures of diabase dike rocks (unit 4) encountered on the south flank of the complex suggest that the dikes sharply cut the supracrustal rocks but have been truncated by the emplacement of the carbonatite. The width of the dikes is uncertain but is likely on the order of several metres. Even though the outcrops are slumped or poorly exposed, the trend of the dikes appears to be generally north and the dip is likely to be steep.

The dikes weather grey black to green black and are black on fresh surface. The dikes are fine grained, equigranular and display a typical diabasic texture on the weathered surface.

This rock unit was not examined in thin section.

### FIRESAND RIVER CARBONATITE COMPLEX

The Firesand River Carbonatite Complex has been dated at 1008 and 1087 Ma by Gittins *et al.* (1967) which places it within the Late Precambrian. The complex consists of sovite, silicocarbonatite, ijolite and rauhaugite. The sovite, silicocarbonatite and ijolite are restricted to the rim of the complex and rauhaugite to the core.

#### Sovite and Silicocarbonatite Rim Rocks

The rocks of unit 5 are peripheral to a ferruginous dolomite core. The rocks are heterogeneous, varying from pure carbonate to nearly pure silicate mineralogy.

*Sovite*

Sovite (unit 5a) weathers white, pink, buff and grey. On fresh surfaces the rocks display similar tints and may become mottled black as the silicate mineral content

increases. The weathered outcrop is commonly lichen–covered and more extensive exposures, such as are present in one or two places on the southern margin of the body, weather to a gruss composed of carbonate rhombs. Along the southern flank some sovite outcrops are porphyritic with large carbonate rhombs up to 10 cm set in a finer–grained matrix. These porphyritic outcrops do not form a mappable unit but can be rather spectacular. Some outcrops tend to break into slabs which, upon close inspection, may be due to preferred orientation of the cleavage directions of the carbonate grains. This feature imparts a foliation to the rock.

In thin section, rocks of this map unit are generally fine to medium grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Relative variations in accessory mineral content impart a banding or mineralogical layering to some exposures.

The mode is highly variable between even closely spaced samples. It is estimated as 0 to 10% apatite, 0 to 30% clinopyroxene, 0 to 10% magnetite, 50 to 100% carbonate, 0 to 30% biotite, 0 to 10% amphibole, and 0 to 10% brown alteration of unknown mineralogy. Several thin sections contain significant olivine to a maximum of 15%.

Apatite forms round to subrounded, more or less equant grains and round–elongate prisms. The grains may be disseminated throughout or crudely segregated into bands or irregular aggregates.

The clinopyroxene consists of two species which are likely gradational into each other. The first is colourless and has a generally equant outline. This pyroxene is anhedral to subhedral, and locally encloses grains of carbonate and biotite. This pyroxene is likely diopsidic.

The second variety of clinopyroxene is pale green to green in colour and tends to be more elongate in habit. Alteration of this variety to acicular amphibole was noted. In some samples alteration of the clinopyroxene has produced a turbid or cloudy appearance. This green pyroxene is likely a sodium– and iron–bearing variety. Variable extinction angles were obtained and some would fall into that of aegirine augite. Both pyroxenes, in places, tend to cluster into aggregates.

Magnetite forms anhedral to subhedral grains which are disseminated throughout. Individual grains may actually be a composite of several grains. The magnetite occurs in association with pyroxene and biotite. Some grains enclose irregular, rounded blebs of carbonate, and/or brown biotite, and a rare grain of apatite is enclosed within magnetite in one sample. Very rarely some magnetite is skeletal. Teal (1979) reported several microprobe analyses of magnetite grains, presumably from samples collected from the calcitic rim rocks of the complex (Table 2). She used the chemistry of coexisting magnetite–ulvospinel and ilmenite–hematite solid solutions to estimate a minimal temperature of emplacement for the Firesand River Carbonatite Complex. She estimated the temperature of crystallization to be approximately 600°C.

The carbonate forms an interlocking mosaic of anhedral grains. It generally occurs interstitial to the other minerals and thus would be the last mineral to crystallize from the carbonatite magma. Teal (1979) reported a large number of microprobe analyses of carbonate grains from the Firesand River Carbonatite Complex (Table 3). She reported that calcite forms the outer ring of the complex and that dolomite–ankerite is restricted to the core. Calcite is absent from the core of the intrusion whereas dolomite and rarely ankerite are present as exsolution phases in the outer ring calcite phase of the complex (Teal 1979). She ob-

**TABLE 2. MICROPROBE ANALYSES OF IRON-TITANIUM OXIDES FROM THE FIRESAND RIVER CARBONATITE COMPLEX, WITH CALCULATED TEMPERATURE (°C) AND LOG $fO_2$ (FROM TEAL 1979).**

| Sample | 10D | | 20 | |
|---|---|---|---|---|
| | Magnetite | Ilmenite | Magnetite | Ilmenite |
| **Weight %** | | | | |
| $Na_2O$ | 0.60 | 0.17 | 0.01 | 0.29 |
| MgO | 0.70 | 0.34 | 1.21 | 3.93 |
| $Al_2O_3$ | 0.34 | 0.10 | 0.27 | 0.23 |
| $SiO_2$ | 0.49 | 0.39 | 0.41 | 0.21 |
| $K_2O$ | | 0.04 | | |
| CaO | 0.03 | 0.05 | 0.20 | 0.04 |
| $TiO_2$ | 5.71 | 49.76 | 9.06 | 52.19 |
| $Cr_2O_3$ | 3.60 | 0.05 | 0.16 | 0.03 |
| MnO | 0.59 | 3.92 | 2.79 | 9.26 |
| Fe | 83.05 | 44.41 | 80.54 | 33.70 |
| Total | 95.81 | 99.23 | 95.76 | 99.88 |
| **Calculated** | | | | |
| $Fe_2O_3$ | 53.02 | 4.26 | 50.56 | 3.27 |
| FeO | 35.35 | 40.58 | 35.04 | 30.75 |
| Total | 99.83 | 99.66 | 99.71 | 100.20 |
| **Mol %** | | | | |
| Ulvospinel | 30.29 | | 36.73 | |
| **Mol %** | | | | |
| $Fe_2O_3$ | | 2.17 | | 1.72 |
| T (°C) | | 600 | | 600 |
| log $fO_2$ | | -22.5 | | -22.5 |

served that at, or near the boundary between the outer calcite rim and dolomite core, some samples contain both dolomite–ankerite and calcite. Using calcite–dolomite equilibrium relations, Teal (1979) calculated presumed crystallization temperatures. The temperatures were low and considered by her to be unreliable.

The mica is biotite and biotite–phlogopite. Biotite is present as irregular, sometimes ragged grains. In some samples the mica is brown to red–brown in colour and displays the pleochroism of biotite. These grains are generally irregular, tabular in form and have been observed to enclose blebs of carbonate and an occasional magnetite grain. In rare instances grains with dark brown rims and light brown cores were observed. In another instance a sample contains biotite with red–brown cores and light yellow–brown rims. Grains enclosing clinopyroxene as well as grains enclosed in clinopyroxene have been observed. Bending of the (001) cleavage was observed in a few specimens but, in general, it is rather uncommon.

Of common and widespread occurrence is biotite–phlogopite. This mica occurs as irregular, tabular to ragged grains and is characterized by a noticeable pale yellow brown (phlogopitic) core and dark red–brown (biotitic) rim. Locally, magnetite is poikilitically enclosed and one sample contains blebs of carbonate within the biotite–phlogopite. Only rarely is phlogopite present without the red–brown rims.

TABLE 3. MICROPROBE ANALYSES OF CARBONATES FROM THE FIRESAND RIVER CARBONATITE EXPRESSED AS MOL % $MgCO_3$, $CaCO_3$, $MnCO_3$ AND $FeCO_3$, WITH CALCULATED TEMPERATURES (FROM TEAL 1979).

| Sample | Ave. of | $MgCO_3$ | $CaCO_3$ | $MnCO_3$ | $FeCO_3$ | T(°C) | Name |
|---|---|---|---|---|---|---|---|
| 2C | 2 | 42.89 | 48.25 | 0.86 | 8.01 | | Fe-dolomite |
| 3A | 2 | 41.51 | 47.59 | 0.72 | 10.19 | | Ankerite |
| 3E | 3 | 41.58 | 43.89 | 1.30 | 13.23 | | Ankerite |
| 4 | 1 | 38.94 | 48.33 | 0.45 | 12.27 | | Ankerite |
| 16 | 1 | 39.17 | 45.96 | 1.93 | 12.94 | | Ankerite |
| 10 | 1 | 1.00 | 98.41 | 0.36 | 0.24 | 129.13 | Calcite |
| 10 | 1 | 33.31 | 49.37 | 1.17 | 16.15 | | Ankerite |
| 10A | 2 | 0.69 | 98.63 | 0.37 | 0.32 | 35.81 | Calcite |
| 10A | 4 | 48.99 | 48.95 | 0.64 | 1.42 | | Dolomite |
| 10B | 2 | 0.97 | 98.37 | 0.23 | 0.44 | 121.47 | Calcite |
| 10C | 1 | 0.79 | 98.68 | 0.21 | 0.32 | 69.85 | Calcite |
| 11 | 2 | 43.42 | 48.30 | 1.17 | 7.13 | | Fe-dolomite |
| 14 | 1 | 37.66 | 48.15 | 1.06 | 13.13 | | Ankerite |
| 20* | 2 | 1.22 | 98.39 | 0.39 | | 179.13 | Calcite |
| 26 | 1 | 0.39 | 99.45 | | 0.16 | | Calcite |
| 28 | 2 | 37.38 | 49.44 | 1.16 | 12.02 | | Ankerite |
| 28 | 1 | 0.44 | 99.31 | 0.20 | 0.05 | | Calcite |
| 29 | 1 | 28.07 | 49.91 | 1.23 | 20.80 | | Ankerite |
| 35 | 2 | 22.62 | 49.87 | 3.63 | 23.89 | | Ankerite |
| 37 | 1 | | 98.86 | 0.28 | 0.85 | | Calcite |
| 49 | 2 | 26.03 | 48.96 | 1.15 | 23.86 | | Ankerite |
| 49 | 3 | 0.38 | 98.22 | 0.31 | 1.09 | | Calcite |
| 54B | 1 | 40.34 | 47.36 | 0.63 | 11.66 | | Ankerite |
| 54B | 2 | 2.26 | 96.53 | 0.57 | 0.64 | 334.17 | Calcite |
| 62 | 1 | 0.09 | 99.61 | 0.31 | | | Calcite |
| 63* | 1 | 2.15 | 96.83 | 0.55 | 0.48 | 321.62 | Calcite |
| 64* | 1 | 1.18 | 98.02 | 0.61 | 0.20 | 170.75 | Calcite |
| 79 | 1 | 0.25 | 99.08 | 0.22 | 0.45 | | Calcite |
| 83 | 1 | 0.49 | 98.16 | 0.99 | 0.36 | | Calcite |
| 87 | 2 | 0.30 | 98.89 | 0.32 | 0.49 | | Calcite |
| 88 | 1 | 0.54 | 98.77 | 0.33 | 0.36 | | Calcite |
| 96 | 1 | 41.92 | 48.45 | 1.71 | 7.92 | | Fe-dolomite |
| 97 | 1 | 39.57 | 48.73 | 0.81 | 10.89 | | Ankerite |

*Dolomite-ankerite exsolution present, no analysis available.

The amphibole occurs as acicular, needle-like crystals with ragged terminations and euhedral cross-sections. The amphibole is likely a sodium-bearing variety. Rarely the amphibole will be turbid and may poikilitically contain tiny grains of magnetite. The crystals may display a pale green pleochroism and, in one case, the crystals occur in radiating aggregates.

A minor, fine-grained, turbid, brown, unidentified alteration is present in a number of samples. This alteration is likely a mixture of iron oxides and biotite and likely the breakdown product of pyroxene, magnetite, and possibly olivine.

Olivine is not common in the sovite, but where present it occurs as anhedral to subhedral grains. In one specimen large skeletal olivine grains are intergrown with carbonate indicating simultaneous crystallization of the two minerals. The skeletal olivine occurs as narrow ribs separated by carbonate. The overall shape of the olivine grain is subhedral. The author has previously observed such skeletal olivine only within the Schryburt Lake Carbonatite Complex (Sage 1988). Olivine

TABLE 4. MICROPROBE ANALYSES OF OLIVINE AND MONTICELLITE FROM THE FIRESAND RIVER CARBONATITE COMPLEX (FROM TEAL 1979).

| | Olivine | | Monticellite |
|---|---|---|---|
| Sample | 20 | 26 | 82B |
| | Oxides (Wt.%) | | |
| $Na_2O$ | 0.50 | 0.33 | 0.25 |
| MgO | 33.72 | 45.23 | 15.63 |
| $Al_2O_3$ | 0.27 | 0.52 | 0.12 |
| $SiO_2$ | 37.20 | 39.59 | 35.85 |
| $K_2O$ | 0.01 | 0.07 | |
| CaO | 0.31 | 0.21 | |
| $TiO_2$ | 0.09 | 0.03 | 0.08 |
| $Cr_2O_3$ | 0.05 | 0.08 | 0.09 |
| MnO | 3.22 | 0.03 | 1.66 |
| Fe tot | 26.75 | 14.40 | 14.77 |
| Total | 102.12 | 100.49 | 100.48 |
| Ave. of | 7 | 3 | 3 |

within the other specimens forms andehdral to subhedral, rounded grains and has undergone alteration to chlorite, serpentine, and rarely possibly iddingsite. The serpentine rims the olivine and occurs along concentric fractures within the mineral. In one specimen the olivine partially encloses apatite and displays some alteration to acicular amphibole and possibly to a yellow to orange chondrodite. Teal (1979) reported three microprobe analyses of olivine minerals, all from the outer calcite zone of the complex (Table 4). For sample 20, she described the olivine as hyalosiderite, and that of sample 26 as chrysolite.

Quartz is present in several samples. It is interstitial to the carbonate, irregular in outline, and generally with a wavy extinction. The quartz may be composed of an aggregate of individual grains. Euhedral crystal faces of carbonate project into the quartz in one sample. Quartz appears to be the last mineral to have formed as it fills cavities within the carbonatite. Several specimens displaying miarolitic cavities occur within this map unit. The cavities generally do not exceed 1 cm in diameter although one cavity is over 4 cm in diameter. The cavities are lined with euhedral, hematite-coated carbonate crystals. Bright, clear, bipyramidal quartz crystals and hematite-coated, euhedral barite crystals may occur perched on the carbonate crystals.

In addition to the major minerals described above, trace to minor amounts of chlorite, sphene, pyrochlore, perovskite, and dark red-brown garnet are present. Microprobe analyses of the garnet were completed by Teal (1979)(Table 5). She reported that the garnet as a group is titaniferous andradite. Sample 86 was classified as melanite and the remaining three as schorlomite (Teal 1979). Streaks, blebs and clots of coarse-grained pyrrhotite occur in some samples of sovite collected from the former Morrison *et al.* claims (Location B on Figure 3). The sulphide mineral content is estimated to be less than 1 volume percent.

### *Ferruginous Sovite*

Ferruginous sovite (unit 5b) is identical to the previously described sovite (unit 5a) except on the weathered surface the rock is pink, yellow-brown, or red-brown in colour. The colouration results from the accumulation of minor amounts of iron oxide on the rock surface from weathering of the iron-bearing carbonate. On fresh surface the rock is pink, brown-pink, to pale brown. In the field it was

TABLE 5. MICROPROBE ANALYSES OF GARNETS FROM THE FIRESAND RIVER CARBONATITE COMPLEX (FROM TEAL 1979).

| Sample | 21 | 76 | 86 | 89 |
|---|---|---|---|---|
| | | (Wt.%) | | |
| $Na_2O$ | 0.22 | 0.36 | 0.09 | 0.27 |
| MgO | 0.92 | 0.37 | 0.65 | 0.49 |
| $Al_2O_3$ | 2.46 | 0.95 | 3.28 | 1.25 |
| $SiO_2$ | 34.26 | 34.15 | 34.83 | 30.88 |
| $K_2O$ | | | | |
| CaO | 33.22 | 32.22 | 33.23 | 31.18 |
| $TiO_2$ | 6.30 | 5.93 | 4.62 | 14.43 |
| $Cr_2O_3$ | 0.12 | 0.08 | 0.01 | 0.12 |
| MnO | 0.09 | 0.23 | 0.39 | 0.55 |
| Fe tot | 21.64 | 23.18 | 21.33 | 19.21 |
| Total | 99.23 | 97.48 | 98.43 | 98.38 |
| Ave. of | 6 | 1 | 3 | 6 |

difficult, if not impossible, to subdivide this rock from the sovitic rim or dolomitic core and thus coding of the accompanying map (Figure 3, Chart A) is rather subjective. The rock is considered by the author to be dominantly calcitic and generally occurs between the calcitic rocks of the rim and dolomitic rocks of the core.

*Silicocarbonatite to Ijolite*

This rock unit (unit 5c) is abundant within the calcite–rich border of the dolomitic core and was classified as mafic carbonate and silicate rock by Parsons (1961, p.25–26). Rocks of this unit are cut by and enclosed within sovite. Rocks of this class may be cumulate phases of the carbonatite, metasomatized xenoliths of wall rock, or dismembered earlier more mafic phases of the complex. Parsons (1961, p.26) considered most rocks of this grouping to be essentially metasomatized greenstones and country rocks. Unless recognizable relict textures or structures are present, xenolithic parentage cannot be determined. Thin section examination disclosed a number of samples to be carbonate–garnet–biotite ijolites. It was impossible to subdivide the ijolitic rocks from the non–ijolitic rocks in the field. In no case was a true ijolite (nepheline plus pyroxene) observed in thin section; all specimens of rocks petrographically identified as ijolite contain large amounts of one or more of the minerals carbonate, garnet, and biotite in addition to nepheline (altered) plus pyroxene.

In thin section, these rocks (unit 5c) are fine to medium grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Rocks of this group are highly variable in mineral composition. The mode is estimated to be 0 to 10% apatite, 0 to 30% clinopyroxene, 0 to 15% magnetite, 10 to 50% carbonate, 0 to 55% biotite, 0 to 30% amphibole, 0 to 35% olivine, and 0 to 30% garnet.

The apatite forms round to subangular grains, anhedral in form. Rarely the grains are elongate. Apatite grains may interlock with pyroxene, more rarely garnet, and have been observed to be poikilitically enclosed within biotite. The grains locally tend to occur in aggregates or clusters of several grains but generally the grains are more or less scattered throughout any given sample.

The clinopyroxene is generally colourless and in places has turbid or clouded rims. The mineral forms anhedral, rarely subhedral, grains. In places, pyroxene poikilitically encloses magnetite and apatite, and it has been observed enclosed in

garnet. The mineral may interlock with biotite and is generally more or less equant even though some elongate grains are present. One sample contains pyroxene with rounded red–brown inclusions which may be former olivine altered to iddingsite.

Clinopyroxene with a pale–green to green pleochroism is also present in this unit and the colourless and green pyroxenes are, in all probability, gradational into each other. This green pyroxene likely contains a higher sodium and iron content than the colourless variety and the more intense green varieties are likely aegirine augite. The green clinopyroxene also poikilitically contains the occasional grain of magnetite and may interlock with biotite and more rarely garnet. Some of the pyroxene is turbid from unidentified alteration and rarely, ragged margins are present where acicular amphibole has formed from the breakdown of pyroxene. Uncommonly a grain of biotite is enclosed within the pyroxene or occurs along the margins of pyroxene. In one specimen pyroxene appears platey and has a subparallel orientation.

On the basis of limited optical observations the clinopyroxene varies from diopsidic augite to aegirine augite in composition. Microprobe analyses by Teal (1979) indicate pyroxene compositions ranging from aegirine to diopside (Table 6).

The magnetite occurs as anhedral to subhedral disseminated grains. Some of the larger grains are likely a composite of several grains. Magnetite is poikilitically enclosed in pyroxene and biotite as well as forming distinct grains interlocked with these minerals. Rarely, one of the larger magnetite grains contains a rounded bleb of carbonate. In one sample the magnetite encloses small grains of red–brown biotite and interlocks with garnet.

The carbonate is anhedral and forms an interlocking mosaic of grains in the more carbonate–rich phases. As the carbonate content decreases, the carbonate becomes an interstitial component.

The mica is biotite, biotite–phlogopite, and phlogopite. The biotite occurs as ragged grains or irregular tabular grains of brown to dark brown colour. Phlogopite has the same habit but is almost colourless to pale yellow brown in colour. Zoning of the mica is common with pale yellow–brown cores (phlogopite) rimmed with red–brown (biotite). In several samples, a biotite grain with a dark brown core and a lighter brown rim was noted. Grains with a dark red–brown biotitic core and a turbid brown rim were also observed. High power magnification of some of the darker coloured cores would suggest the possibility that the darkening may be caused by a very fine–grained dusting of magnetite. In samples containing larger amounts of biotite, the grains may have a crude subparallel orientation which thus defines a schistosity. The mica interlocks with pyroxene, magnetite, amphibole, garnet, and blebs of carbonate. In one instance tabular grains of magnetite occur parallel to the (001) cleavage of the mica. In one or more samples, both phlogopite and biotite have developed narrow colourless rims. One example of phlogopite intergrown with carbonate implies simultaneous crystallization of the two minerals. Biotite may occur as crude but more or less distinct rims on an occasional magnetite grain. Mottling of colour in mica grains in several biotite–phlogopite–bearing samples implies that heterogeneous compositional variations may be present. Two examples of an alternating ribbon–like pale yellow brown and red–brown pleochroism across biotite–phlogopite grains were noted. Rarely bending of the (001) cleavage was noted on the larger grains and some of the larger grains with inclusions take on a poikiloblastic appearance. Teal (1979) analyzed a large number of mica grains and found considerable vari-

**TABLE 6. MICROPROBE ANALYSES OF PYROXENES FROM THE FIRESAND RIVER CARBONATITE COMPLEX (WEIGHT PERCENT). (FROM TEAL 1979).**

| Sample | 21 | 33 | 34 | 55 | 57 |
|---|---|---|---|---|---|
| $Na_2O$ | 0.37 | 2.67 | 12.14 | 3.71 | 5.71 |
| MgO | 15.52 | 7.34 | 2.22 | 8.54 | 7.49 |
| $Al_2O_3$ | 0.82 | 0.84 | 1.45 | 0.94 | 0.53 |
| $SiO_2$ | 53.59 | 51.70 | 53.46 | 52.91 | 52.95 |
| $K_2O$ | | 0.02 | 0.03 | 0.07 | 0.03 |
| CaO | 23.15 | 19.81 | 3.28 | 17.92 | 14.04 |
| $TiO_2$ | 0.17 | 0.51 | 0.94 | 0.55 | 1.25 |
| $Cr_2O_3$ | 0.31 | 0.18 | 0.06 | 0.08 | 0.22 |
| MnO | 0.11 | 0.87 | 0.23 | 0.70 | 0.41 |
| FeO | 4.55 | 16.06 | 24.89 | 14.93 | 16.04 |
| Total | 100.59 | 100.00 | 98.70 | 100.35 | 98.67 |
| Ave. of | 2 | 11 | 3 | 3 | 2 |
| Name | Di | Na-FA | Ae | A-A | A-A |

| Sample | 62 | 76 | 79 | 81 | 82B |
|---|---|---|---|---|---|
| $Na_2O$ | 1.29 | 2.89 | 4.46 | 0.16 | 0.23 |
| MgO | 9.91 | 7.99 | 8.19 | 17.86 | 17.92 |
| $Al_2O_3$ | 0.88 | 0.68 | 1.04 | 0.28 | 0.13 |
| $SiO_2$ | 51.44 | 52.32 | 52.92 | 54.87 | 54.94 |
| $K_2O$ | 0.02 | | 0.02 | 0.04 | 0.02 |
| CaO | 22.20 | 19.61 | 16.24 | 25.72 | 25.71 |
| $TiO_2$ | 0.41 | 0.28 | 0.48 | 0.14 | 0.14 |
| $Cr_2O_3$ | 0.20 | 0.11 | 0.13 | 0.09 | 0.08 |
| MnO | 0.54 | 1.08 | 0.53 | 0.03 | 0.16 |
| FeO | 12.65 | 15.66 | 14.90 | 1.25 | 1.28 |
| Total | 99.54 | 100.62 | 98.91 | 100.44 | 100.61 |
| Ave. of | 4 | 3 | 3 | 3 | 3 |
| Name | Na-S | Na-Fa | A-A | Di | Di |

| Sample | 86 | 87 | 88 | 89 |
|---|---|---|---|---|
| $Na_2O$ | 0.68 | 2.15 | 3.59 | 2.49 |
| MgO | 13.24 | 9.86 | 7.37 | 6.66 |
| $Al_2O_3$ | 0.97 | 0.95 | 0.89 | 0.81 |
| $SiO_2$ | 53.43 | 52.05 | 52.02 | 51.48 |
| $K_2O$ | | 0.01 | 0.02 | 0.01 |
| CaO | 24.72 | 20.29 | 18.19 | 19.93 |
| $TiO_2$ | 0.16 | 0.49 | 0.26 | 0.72 |
| $Cr_2O_3$ | 0.11 | 0.17 | 0.10 | 0.11 |
| MnO | 0.61 | 0.16 | 0.54 | 1.12 |
| FeO | 8.22 | 14.17 | 16.38 | 17.20 |
| Total | 102.14 | 100.30 | 99.36 | 99.53 |
| Ave. of | 2 | 3 | 4 | 5 |
| Name | S | Na-A | A-A | Na-FS |

Di - diopside; Na-A - sodic augite; Na-FA - sodic ferroaugite; Ae - aegirine; A-A - aegirine augite; S - salite; Na-S -sodic salite; Na-FS - sodic ferrosalite.

ation in mica composition (Table 7). She placed the division between phlogopite and biotite at a ratio of Mg:Fe of 2:1. The Fe:Mg ratio varies considerably producing a range in composition from $annite_8$ to $annite_{82}$. Teal (1979) did not attempt to determine the compositional variation within an individual mica grain which is apparent in the changes in pleochroism at many of the grains from their core to rim.

**TABLE 7. MICROPROBE ANALYSES OF MICAS FROM THE FIRESAND RIVER CARBONATITE COMPLEX (WEIGHT PERCENT). (FROM TEAL 1979).**

| Sample | 3E | 10 | 10A | 10B | 10C | 10D |
|---|---|---|---|---|---|---|
| $Na_2O$ | 1.51 | 0.80 | 0.83 | 0.74 | 0.54 | 0.73 |
| MgO | 22.48 | 23.79 | 23.43 | 22.50 | 21.59 | 24.02 |
| $Al_2O_3$ | 14.84 | 12.52 | 10.79 | 11.55 | 15.60 | 12.53 |
| $SiO_2$ | 38.03 | 40.00 | 40.33 | 38.14 | 37.57 | 39.47 |
| $K_2O$ | 8.20 | 9.76 | 9.68 | 9.13 | 9.48 | 9.74 |
| CaO | 0.05 | | | 0.01 | 0.05 | |
| $TiO_2$ | 2.75 | 1.04 | 1.26 | 2.55 | 2.77 | 1.44 |
| $Cr_2O_3$ | | 0.05 | 0.04 | 0.03 | 0.03 | |
| MnO | 0.17 | 0.13 | 0.12 | 0.35 | 0.16 | 0.13 |
| $Fe_{tot}$ | 6.66 | 6.61 | 8.44 | 9.18 | 6.99 | 6.88 |
| $H_2O$ | 4.15 | 4.13 | 4.10 | 4.05 | 4.13 | 4.13 |
| Total | 98.84 | 98.83 | 99.02 | 98.23 | 98.91 | 99.07 |
| Ave. of | 4 | 3 | 2 | 2 | 3 | 3 |

| Sample | 21 | 24 | 26 | 29 | 33 | 34 |
|---|---|---|---|---|---|---|
| $Na_2O$ | 2.04 | 0.65 | 0.90 | 0.54 | 0.36 | 0.57 |
| MgO | 21.85 | 24.97 | 20.60 | 17.41 | 9.00 | 13.45 |
| $Al_2O_3$ | 14.53 | 8.16 | 15.04 | 11.88 | 13.01 | 11.62 |
| $SiO_2$ | 38.93 | 41.05 | 37.68 | 37.59 | 34.88 | 36.98 |
| $K_2O$ | 7.50 | 9.92 | 9.28 | 9.61 | 9.37 | 9.64 |
| CaO | 0.22 | 0.11 | 0.05 | 0.08 | 0.09 | 0.08 |
| $TiO_2$ | 0.58 | 0.08 | 2.36 | 2.71 | 4.07 | 3.74 |
| $Cr_2O_3$ | 0.05 | 0.05 | 0.08 | 0.02 | 0.01 | 0.03 |
| MnO | 0.08 | 0.26 | 0.17 | 0.10 | 0.84 | 1.15 |
| $Fe_{tot}$ | 9.35 | 9.07 | 8.23 | 15.50 | 25.01 | 18.47 |
| $H_2O$ | 4.13 | 4.05 | 4.08 | 3.97 | 3.81 | 3.90 |
| Total | 99.29 | 98.37 | 98.65 | 99.41 | 100.43 | 99.62 |
| Ave. of | 1 | 2 | 2 | 3 | 1 | 1 |

| Sample | 34 | 35 | 54B | 62 | 63 | 64 |
|---|---|---|---|---|---|---|
| $Na_2O$ | 0.45 | 1.24 | 0.39 | 0.27 | 0.39 | 0.50 |
| MgO | 17.68 | 23.03 | 19.76 | 10.54 | 22.89 | 15.45 |
| $Al_2O_3$ | 11.44 | 10.83 | 16.80 | 11.59 | 7.78 | 8.88 |
| $SiO_2$ | 39.12 | 40.98 | 35.98 | 36.28 | 40.64 | 38.50 |
| $K_2O$ | 9.79 | 8.74 | 9.97 | 9.60 | 10.18 | 9.60 |
| CaO | 0.16 | 0.14 | 0.13 | 0.06 | 0.11 | 0.15 |
| $TiO_2$ | 1.72 | 0.55 | 4.39 | 4.31 | 0.62 | 1.98 |
| $Cr_2O_3$ | 0.06 | 0.04 | 0.11 | 0.04 | 0.03 | 0.02 |
| MnO | 1.00 | 0.13 | | 0.85 | 0.18 | 0.77 |
| $Fe_{tot}$ | 14.45 | 8.74 | 8.01 | 22.69 | 12.30 | 19.92 |
| $H_2O$ | 4.01 | 4.10 | 4.12 | 3.95 | 4.02 | 3.89 |
| Total | 99.88 | 98.56 | 99.64 | 100.08 | 99.14 | 99.66 |
| Ave. of | 2 | 1 | 1 | 3 | 3 | 3 |

Continued.

TABLE 7. CONTINUED.

| Sample | 76 | 79 | 71 | 82B | 83 | 86 |
|---|---|---|---|---|---|---|
| $Na_2O$ | 0.51 | 0.56 | 0.73 | 0.34 | 0.20 | 0.64 |
| MgO | 12.76 | 15.12 | 26.76 | 22.88 | 22.28 | 18.79 |
| $Al_2O_3$ | 11.62 | 11.40 | 11.29 | 16.11 | 10.85 | 14.26 |
| $SiO_2$ | 37.17 | 38.17 | 41.82 | 37.68 | 40.37 | 37.85 |
| $K_2O$ | 9.91 | 9.62 | 9.89 | 10.09 | 10.02 | 9.82 |
| CaO | 0.08 | 0.06 | 0.15 | 0.08 | 0.14 | 0.07 |
| $TiO_2$ | 1.76 | 1.98 | 0.21 | 2.13 | 0.02 | 0.58 |
| $Cr_2O_3$ | 0.08 | | 0.02 | | 0.02 | 0.02 |
| MnO | 0.86 | 0.48 | 0.16 | 0.25 | 0.43 | 0.71 |
| Fetot | 22.81 | 17.84 | 3.77 | 6.73 | 10.02 | 13.67 |
| $H_2O$ | 3.89 | 3.92 | 4.20 | 4.19 | 4.05 | 4.05 |
| Total | 101.44 | 99.15 | 99.00 | 100.48 | 98.40 | 110.46 |
| Ave. of | 1 | 4 | 3 | 2 | 1 | 3 |

| Sample | 87 | 88 | 89 | 96 | 97 |
|---|---|---|---|---|---|
| $Na_2O$ | 0.46 | 0.51 | 0.38 | 1.01 | 1.62 |
| MgO | 8.81 | 11.79 | 10.11 | 21.12 | 22.33 |
| $Al_2O_3$ | 11.26 | 11.66 | 12.60 | 11.27 | 12.87 |
| $SiO_2$ | 36.33 | 37.13 | 35.74 | 40.16 | 39.52 |
| $K_2O$ | 9.13 | 9.46 | 9.23 | 9.27 | 7.90 |
| CaO | 0.03 | 0.01 | 0.28 | 0.02 | 0.03 |
| $TiO_2$ | 4.48 | 3.65 | 2.74 | 0.95 | 1.81 |
| $Cr_2O_3$ | 0.04 | 0.07 | 0.03 | 0.03 | 0.15 |
| MnO | 0.39 | 0.59 | 0.98 | 0.03 | 0.20 |
| Fetot | 25.40 | 21.50 | 23.87 | 10.73 | 7.60 |
| $H_2O$ | 3.82 | 3.89 | 3.81 | 4.05 | 4.11 |
| Total | 100.15 | 100.26 | 99.77 | 98.64 | 98.14 |
| Ave. of | 3 | 2 | 6 | 4 | 2 |

The amphibole occurs as acicular to fibrous, anhedral to euhedral crystals which are colourless to pale green in colour. The amphibole is likely the sodium–bearing tremolite, richterite. The crystals generally are oriented in a random pattern, rarely as crudely radiating aggregates. The amphibole poikilitically encloses magnetite, rarely carbonate and generally has ragged terminations. Traces of possible clinopyroxene were noted enclosed in amphibole in two samples. The amphibole is, in some cases, likely a breakdown product of the clinopyroxene. Microprobe analyses by Teal (1979) indicated the amphibole varies from magnesio–arfvedsonite to richterite in composition (Table 8).

Teal (1979) reported that the richterite is colourless and that the magnesio–arfvedsonite is blue–green and distinctly pleochroic. She also observed that the richterite occurs dominantly in carbonate–biotite rocks and that the magnesio–arfvedsonite is restricted to calcite and dolomite–ankerite rocks. Teal (1979) suggested that the lower Mg content of the magnesio–arfvedsonite, which is typical of the core rocks of the complex, implies that the central core of the intrusion was emplaced at a lower temperature and, therefore, forms a later phase of the intrusion. She apparently assumed that the carbonate–biotite rocks were all part of the intrusion and possibly of magmatic origin. In the author's opinion, some of these carbonate–biotite rocks may be the result of extensive metasomatic reaction of the carbonatite magma with wall rock fragments. The question then arises: does richterite suggest a rock of metasomatic origin and magnesio–arfvedsonite a rock

**TABLE 8. MICROPROBE ANALYSES OF AMPHIBOLES FROM THE FIRESAND RIVER CARBONATITE COMPLEX (WEIGHT PERCENT). (FROM TEAL 1979).**

| Sample | 6 | 10 | 10A | 10B | 10C | 10D |
|---|---|---|---|---|---|---|
| $Na_2O$ | 6.68 | 6.10 | 6.05 | 6.05 | 6.09 | 7.09 |
| MgO | 15.62 | 22.31 | 22.33 | 22.00 | 21.90 | 22.52 |
| $Al_2O_3$ | 0.30 | 0.52 | 0.48 | 0.64 | 0.80 | 0.50 |
| $SiO_2$ | 55.20 | 56.06 | 56.41 | 55.89 | 56.32 | 57.22 |
| $K_2O$ | 3.49 | 1.53 | 1.44 | 1.68 | 1.50 | 1.11 |
| CaO | 3.07 | 7.08 | 7.23 | 6.98 | 6.99 | 5.96 |
| $TiO_2$ | 0.46 | 0.51 | 0.56 | 0.75 | 0.60 | 0.30 |
| $Cr_2O_3$ | 0.08 | 0.07 | 0.02 | 0.04 | 0.07 | 0.10 |
| MnO | 0.23 | 0.10 | 0.26 | 0.16 | 0.19 | 0.14 |
| Fetot | 12.68 | 3.39 | 3.25 | 3.38 | 3.68 | 3.68 |
| $H_2O$ | 2.05 | 2.14 | 2.15 | 2.13 | 2.15 | 2.17 |
| Total | 97.81 | 99.81 | 100.18 | 99.70 | 100.29 | 100.79 |
| Ave. of | 8 | 4 | 4 | 3 | 3 | 4 |
| Name | MA | R | R | R | R | R |

| Sample | 20 | 24 | 26 | 49 | 54B1 |
|---|---|---|---|---|---|
| $Na_2O$ | 5.24 | 5.69 | 6.69 | 5.56 | 9.09 |
| MgO | 21.25 | 21.28 | 23.39 | 20.38 | 14.47 |
| $Al_2O_3$ | 0.40 | 0.53 | 1.22 | 0.17 | 0.69 |
| $SiO_2$ | 56.52 | 56.29 | 55.89 | 56.10 | 55.94 |
| $K_2O$ | 1.30 | 2.05 | 0.18 | 3.23 | 2.24 |
| CaO | 7.96 | 6.57 | 7.64 | 5.83 | 0.36 |
| $TiO_2$ | 0.24 | 0.20 | 0.33 | 0.26 | 0.40 |
| $Cr_2O_3$ | 0.06 | 0.08 | 0.10 | | 0.04 |
| MnO | 0.25 | 0.19 | | 0.40 | |
| Fetot | 4.68 | 4.57 | 1.46 | 5.53 | 14.02 |
| $H_2O$ | 2.14 | 2.13 | 2.15 | 2.10 | 2.05 |
| Total | 100.04 | 99.58 | 99.05 | 99.56 | 99.29 |
| Ave. of | 2 | 3 | 2 | 3 | 1 |
| Name | R | R | R | MA | MA |

| Sample | 54B2 | 81 | 83 | 96 | 97 |
|---|---|---|---|---|---|
| $Na_2O$ | 6.78 | 6.65 | 6.60 | 9.77 | 10.14 |
| MgO | 20.36 | 23.71 | 19.41 | 15.19 | 13.80 |
| $Al_2O_3$ | 0.23 | 0.62 | 0.52 | 1.20 | 2.21 |
| $SiO_2$ | 56.90 | 56.93 | 55.78 | 54.33 | 53.26 |
| $K_2O$ | 2.86 | 0.71 | 1.96 | 1.10 | 0.27 |
| CaO | 4.06 | 7.20 | 5.35 | 0.33 | 0.38 |
| $TiO_2$ | 0.19 | 0.25 | 0.08 | 0.81 | 0.65 |
| $Cr_2O_3$ | 0.26 | 0.07 | 0.10 | 0.25 | 0.06 |
| MnO | | 0.15 | 0.66 | 0.07 | 0.17 |
| Fetot | 6.00 | 1.15 | 6.92 | 13.98 | 15.47 |
| $H_2O$ | 2.12 | 2.16 | 2.10 | 2.04 | 2.03 |
| Total | 99.76 | 99.60 | 99.48 | 99.07 | 98.44 |
| Ave. of | 2 | 4 | 5 | 6 | 3 |
| Name | MA | R | MA | MA | MA |

MA - Magnesio-arfvedsonite; R - Richterite

of magmatic origin? This problem warrants additional study and the development of criteria to separate magmatic from possible metasomatic amphibole.

Olivine is an uncommon mineral but is present in significant quantities in several specimens. The sample with the highest olivine content (estimated at 35%) displays subhedral somewhat elongated grains altered to serpentine along grain boundaries and curved internal fractures. In those samples with relatively minor olivine content, the olivine may be completely altered to chlorite (or bowlingite?) and serpentine. In one sample the olivine forms rounded grains which have traces of chondrodite (?) and dusty magnetite along the edges.

Garnet is present in a number of samples as dark red–brown grains of anhedral to subhedral form. The garnet occurs in irregular, rounded, composite grains with a sieve–like appearance. The garnet may enclose biotite, clinopyroxene, apatite, magnetite, and carbonate. The sieve–like appearance suggests that the garnet may, in some cases, be poikiloblastic.

A number of samples contain a brown to red–brown alteration which is optically unresolvable. This material is thought to be largely a mixture of iron oxides and biotite.

Chlorite is present in several samples possibly after olivine and/or pyroxene.

Rare sphene is present as euhedral to subhedral crudely wedge–shaped crystals.

Perovskite is abundant in two samples and consists of relatively small anhedral to euhedral (cubic) grains. The perovskite is commonly closely associated with magnetite. The mineral is weakly anisotropic, disseminated, and has been observed to be poikilitically enclosed in biotite–phlogopite.

One sample poikilitically contains scattered tiny grains in biotite. The tiny grains have dark brown radioactive bombardment haloes enclosing them and are probably zircons.

Possible zeolite(s) as very fine–grained, fibrous masses are present in one sample and analcite (?) may be present in another. The analcite (?) is present within a homogeneous section of core which contains round blebs of carbonate, up to 1 cm in diameter, thought to possibly have been formed by a process of liquid immiscibility. The supposed analcite is turbid, isotropic and occurs within the centre of the coarse–grained carbonate drop. Two specimens displaying rounded immiscible (?) carbonate drops were examined and possible zeolitic minerals are present within the centres. Most of the suspected zeolitic (?) material is colourless, has low birefringence, and is acicular to fibrous.

Plagioclase of albitic composition is present in one sample. This mineral is clear, anhedral, ragged in outline, occurs interstitially; and interlocks with biotite and magnetite. The feldspar encloses carbonate, sodic pyroxene, magnetite, and possibly some traces of biotite. Albite twinning is present but not common.

Nepheline is present in one sample. This mineral occurs as anhedral grains interlocked with biotite and amphibole. Traces of carbonate may be enclosed within the nepheline.

One thin section was prepared from a metavolcanic xenolith displaying a well developed reaction rim. In thin section the rim consists of a fine–grained interlocking mass of deep red–brown biotite. The metavolcanic rock is composed of carbonate, minor, turbid, ragged, green clinopyroxene, and a granoblastic mosaic of plagioclase. The sovite enclosing the xenolith is a biotite–amphibole–pyroxene

variety. The pyroxene forms cores to pleochroic colourless to pale green, turbid, ragged amphibole. The pyroxene grains are scattered at random. The biotite forms tabular, deep red–brown grains.

*Ijolite*

A subunit of the silicocarbonatite (Unit 5c) is ijolite. This unit is recognizable in thin section but not in the field. True ijolite (nepheline plus pyroxene) was not observed and generally half of any given sample consists of garnet, biotite, and carbonate. No systematic pattern of distribution of the ijolite was observed.

On weathered surface this rock type is indistinguishable from the silicocarbonatites.

In thin section the rock is fine to medium grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Uncommonly the rock is inequigranular–seriate and rarely it is hypidiomorphic. The mode is estimated as 0 to 20% garnet, 10 to 30% biotite, 0 to 10% magnetite, 5 to 30% nepheline, 0 to 5% apatite, 15 to 30% clinopyroxene, and 10 to 30% carbonate.

The garnet is anhedral to subhedral, dark red–brown in colour, and forms anhedral irregular clots with abundant inclusions that give the impression of a sieve texture. The garnet was observed to enclose clinopyroxene, nepheline, and carbonate, and rarely it is enveloped in biotite. Rarely the garnet may enclose apatite or biotite. Garnet in one sample rims clinopyroxene in places, and in another it rims biotite. One sample contains euhedral garnet which has dark red–brown cores and pale brown rims that suggest a compositional zonation. The grains are rarely crudely skeletal in habit. Of all the rock types, ijolite contains the most abundant and ubiquitous garnet.

The biotite occurs as irregular, anhedral grains that are brown, green–brown, and red–brown in colour. In some samples the grains are ragged and in other samples they are more or less tabular. In some samples biotite is zoned. Biotite–phlogopite is present as pale yellow–brown cores rimmed with red–brown biotite. The biotite interlocks with pyroxene, garnet and nepheline. In places mica encloses carbonate, apatite, magnetite, pyroxene, nepheline and garnet. Several specimens contain pale yellow–brown phlogopite rather than biotite. Biotite, however, is the dominant of the two micas.

Magnetite occurs as disseminated anhedral grains. This mineral appears to be closely associated with biotite and garnet. While present in nearly all samples, it is of minor importance and appears to occur in smaller quantities within the ijolitic rocks than the other rock types.

Nepheline is interstitial, anhedral to almost euhedral and blocky in outline. The nepheline varies from almost fresh to totally altered. Where altered, it breaks down to a very fine–grained fibrous mass, possibly a zeolite(s). Cancrinite is another common alteration product. Altered nepheline has developed a ragged serrate pattern where the alteration penetrates along the "C" crystallographic axis of the crystal. Where nepheline occurs interstitially, it interlocks with clinopyroxene. It has been observed to enclose clinopyroxene and apatite. Within two samples the nepheline forms relatively large poikiloblastic grains which enclose clinopyroxene. Where enclosed within nepheline the clinopyroxene tends to occur as round blebs in a random orientation.

The apatite occurs as round to round–elongate grains and appears as discrete grains or poikilitically enclosed within most of the other mineral phases. The apatite content of this unit is generally lower than the other rock types even though it is ubiquitous.

The clinopyroxene varies from colourless to green and these two extremes appear gradational into each other. The green varieties are likely sodium– and iron–rich and may be aegirine augite in composition. The colourless grains tend to be equant and locally enclose apatite and sphene. The mineral interlocks with nepheline, garnet, and biotite. Green clinopyroxene is dominant over the colourless variety. This pyroxene tends to be acicular and locally is poikilitically enclosed in nepheline. In one sample biotite occurs as isolated red–brown grains along the flanks of the pyroxene grain.

Carbonate is anhedral and always interstitial to the other minerals. Traces of very tiny grains, probably zircon, are poikilitically enclosed in biotite in one sample. These grains are accompanied by radioactive bombardment haloes. Chlorite and albite were noted in one or more samples. Sphene is occasionally present as euhedral to subhedral, wedge–shaped crystals.

One sample contains large irregular grains of alkali feldspar. These grains are oikocrysts and enclose altered nepheline, clinopyroxene, and blebs of carbonate. The feldspar content of this one sample is estimated as 10% or more and the rock's composition is close to malignite.

#### *Biotitite*

Unit 5d is minor in abundance and of local occurrence. It is almost exclusively composed of biotite. The biotitite is black on fresh and weathered surface and varies from fine to coarse grained. The best examples of biotitite occur along fractures and the margins of carbonatite dikes that cut mafic metavolcanics. Most biotitite appears to have formed by reaction between wall rocks and intruding carbonatite magma. Rocks of this unit were not examined in thin section.

Biotitite outcrops near the southern margin of the complex were interpreted by Parsons (1961) to be metasomatized wall rock.

### Rauhaugite Core Rocks

#### *Ferruginous Dolomite*

The core of the complex consists of ferruginous dolomite (unit 6a) and is poorly exposed. Study of this rock unit was seriously hindered by a lack of fresh samples. Diamond drill core from the early drilling of Algoma Steel Corporation has been lost and sampling was restricted to material from the bottom of a deep prospect pit within a very old trench. The rock that does outcrop within the core is heavily coated with iron oxide. This coating consists of rusty brown to red, pulverulent, earthy hematite and goethite. Locally, a very fine–grained crystalline hematite is present. Observations in old, partially filled trenches indicate that in places this hematite capping approaches 1 m in thickness. This hematite first drew prospectors' attention to the complex (Canadian Mining Journal 1924). Within the deep pit, coarse–grained deep red carbonate and fine–grained buff coloured carbonate are exposed. This carbonate zone appears to be a breccia that may occupy an intermediate position between the hematite cap and the unweathered dolomite. Samples from the bottom of the pit and presumed to represent unweathered carbonatite are fine grained and have a mottled light yellow–brown and grey fresh surface.

In thin section, the texture of samples of the dolomitic rock is fine grained, massive, equigranular, allotriomorphic with curved to lobate grain boundaries. The rock contains 75 to 95% carbonate and the remainder consists of magnetite, apatite, and traces of biotite and barite.

The apatite forms subhedral to euhedral prismatic grains and the magnetite occurs as anhedral to euhedral grains. Some of the grains are crudely skeletal and a limonitic alteration forms along the margins of some grains. The apatite tends to occur in aggregates in one specimen.

The carbonate forms an interlocking mosaic of anhedral grains. Some of the carbonate is turbid, presumably from dusty iron oxide inclusions.

Some samples of diamond drill core assayed by Algoma Steel Corporation contained 20% or more iron over short sections at various depths (Assessment Files Research Office, Ontario Geological Survey, Toronto). There is a distinct possibility that sideritic phases are present within the core of the complex. Niobium assays accompanying the iron assays indicate that the rauhaugite (dolomitic) core rocks are deficient in niobium with respect to the calcitic rim rocks.

### *Barite–quartz Phase*

Barite–quartz float was observed at several sites within the dolomite core. The material was not seen in outcrop but was present in slumped blocks. The presence of barite–quartz within the rauhaugite core of the complex was the subject of a study by Heinrich and Vian (1967). The samples observed by the author consist of platey barite with euhedral crystal faces and euhedral to subhedral smoky quartz crystals. The barite crystals, up to 4–5 cm long, are coated with hematite. The quartz is smoky with grey rims and forms crystals up to 8 and 9 cm in length. Carbonate is associated with the barite and quartz and Heinrich and Vian (1967, p.225) reported that ferruginous apatite coats the barite and quartz.

Heinrich and Vian (1967, p.253) subdivided the quartz rocks into two types: (1) a fine–grained green–grey aggregate of ankeritic dolomite, chlorite and quartz; and (2) a coarse–grained pink dolomite, barite and quartz rock.

Heinrich and Vian (1967, p.254) prepared thin sections from the fine–grained variety which was not found by the author. They described the quartz grains in thin section as highly irregular, deeply embayed, with undulatory extinction and mosaic structure. The quartz also displays striations or subparallel lines of minute "bubble–train" inclusions. The inclusions have the same orientation throughout a single thin section and are independent of the optical orientation of the quartz grains. The associated dolomite displays zones of variable iron content, and pyrite is locally present as aggregates associated with chlorite. Minute vugs contain minute barite and chalcopyrite crystals.

Thin sections were also prepared by Heinrich and Vian (1967, p.254– 255) of the coarse–grained variety and this work was not duplicated by the author. The quartz crystals were all described as broken at the base, corroded and embayed by carbonate, fractured and veined with carbonate and granulated. The barite is also corroded and replaced by dolomite and both the quartz and barite have a thin coating of ferruginous apatite.

Heinrich and Vian (1967, p.257) gave four characteristics of the quartz: (1) it is the earliest mineral formed; (2) it occurs as grains and blocks of broken crystals; (3) it is localized and relatively rare within the carbonatite; and (4) it displays metamorphic textures. On the basis of these observations Heinrich and Vian (1967, p.255) proposed that the barite–quartz rock resulted from the introduction of dolomite, barite, and apatite into quartzite xenoliths.

The author has observed euhedral barite and quartz crystals within miarolitic cavities within the sovite phases of the intrusion close to the inferred contact with the rauhaugite. Barite was also observed within thin sections of the rauhaugite

itself. Quartzite is unknown within proximity to the intrusion even though outcrops are not sufficiently abundant to preclude its presence.

The author is of the opinion that the quartz and barite occupy very local, late stage magma or hydrothermal vein fillings of fractures within the rauhaugite core of the complex. The silica may be a product of late-stage silicification "geochemical recycling" or "repetitive utilization" of silica which has been released from more siliceous wall rocks during fenitization as suggested by Heinrich and Vian (1967, p.257).

### Dike Rocks

Dike rocks (unit 7) of carbonatitic affinity are abundant in the rocks surrounding the Firesand River Carbonatite Complex as well as in the supracrustal rocks of the region. The lamprophyres and carbonate dikes reported in the numerous early descriptions of the gold deposits of the area as well as the numerous thin, rusty weathering, radioactive dikes exposed in road cuts of Highway 101 and 17 are likely products of the same magmatic event. This possibility has been previously suggested by Parsons (1961, p.27).

#### *Sovite Dikes*

Dikes of largely carbonate composition (unit 7a) are present at several locations. The most notable occurrence being location "B" on the former Morrison *et al.* claims. At this location, greenstone, sovite, and silicocarbonatite occur in a more or less haphazard fashion. The occurrence is likely a series of closely spaced dikes. Sovite containing pyrochlore, actinolite, pyrrhotite, and phlogopite is well exposed. Petrographically this rock is identical to the main sovite phase described above.

#### *Silicocarbonatite Dikes*

A large dike of this rock type (unit 7b) was observed south of the complex within a streambed (reference number 1247 on Figure 3). The outcrops display a pronounced banding which, upon weathering, gives rise to a ribbed appearance. The ribbed weathering is a function of the variable silicate mineral content between the various bands. The dike lies roughly parallel to the stream and is 5 m wide. Banding is on the order of 7 to 10 cm and some bands are sovite in composition. This dike is petrographically identical to silicocarbonatite described above. Teal (1979) mapped several silicocarbonatite dikes cutting intermediate to mafic metavolcanics west of the carbonatite complex (reference numbers 1222-24 and 1239-42 on Figure 3).

The strike and dip of this dike suggests that it is likely a cone-sheet intrusion occupying a ring fracture conformable to the contact of the main intrusive complex and its enclosing wall rocks.

#### *Lamprophyre Dikes*

Cutting the silicocarbonatite dike south of the complex are a series of dikes which appear to be oriented radial to the Firesand River Carbonatite Complex. These dikes consist of lamprophyre (unit 7c) and ferruginous carbonate (unit 7d). The dikes cut the banded and ribbed silicocarbonatite dike (Unit 7b) at roughly right angles to the strike of the dike.

The lamprophyres are up to 20 cm in width. In thin section the dike rock is fine grained, massive, inequigranular-seriate, allotriomorphic with curved to

straight grain boundaries. The mode is estimated to be clinopyroxene 15%, garnet 25%, biotite 40%, magnetite 5%, carbonate 15% and traces of sphene.

Clinopyroxene forms subhedral grains with a pale green pleochroism. The grains are rimmed with very fine-grained, acicular amphibole, creating ragged grain edges on the pyroxene. Garnet is anhedral to euhedral, deep red-brown in colour and weakly anisotropic. Biotite is present as tabular, interlocking, anhedral, red-brown grains. Magnetite is anhedral to euhedral and disseminated throughout the rock. Carbonate is present as anhedral interstitial grains. There is a variation in grain size as well as relative proportions of the minerals within the thin section, implying banding on a microscopic scale.

Petrographically the dike is a magnetite-pyroxene-garnet-biotite silicocarbonatite, and is petrographically indistinct from some samples of silicocarbonatite collected from the calcitic rim of the main complex. The term *lamprophyre* was used to distinguish this late dike from an older silicocarbonatite dike that it cuts. While inequigranular in texture it is not truly porphyritic, a characteristic of lamprophyre (AGI 1987).

### *Ferruginous Carbonate*

Also cutting the silicocarbonatite dike normal to the banding and parallel to those dikes mapped as lamprophyre (Unit 7c), are distinctive rusty brown weathering carbonate dikes (unit 7d). These dikes reach a maximum width of 17 cm and may contain up to 1 or 2% pyrite.

In a thin section prepared from one of these dikes, the rock is fine grained, massive, equigranular, allotriomorphic with curved grain boundaries. The mode is estimated as 5% quartz, 10% plagioclase and 85% carbonate.

The quartz is very fine grained and interstitial to the carbonate. Plagioclase is also interstitial to the carbonate, very fine grained and locally is interlocked with quartz. The larger plagioclase grains are turbid. Some plagioclase and perhaps some of the quartz is undoubtedly xenocrystic. The carbonate is anhedral and forms an interlocking mosaic of anhedral grains. The carbonate is turbid, possibly from enclosed iron oxide.

In outcrop, these dikes are similar to numerous small, radioactive, rusty brown carbonatite dikes found in road cuts along Highways 101 and 17.

## PETROLOGY

A suite of carefully selected outcrop samples, drill core samples from the 1972 drilling by Algoma Ore Properties, and fresh samples collected by S. Teal were submitted for complete rock analysis (Appendix A, Table A-2, A-3). Samples collected by Teal are prefixed "ST" and are essentially confined to the outer rim of the complex. Lack of outcrop, deep weathering, and loss of all core obtained in previous drilling has seriously hampered determining the chemical composition of the complex.

The inability to determine the origin of various silicocarbonatite samples places severe constraints on using the analyses of these rocks to speculate on melt chemistry. Rocks of this group may be cumulates, highly altered xenoliths, or dikes.

Carbonatites are considered to involve the process of liquid immiscibility during their development (Nash 1972; Hamilton *et al.* 1979; LeBas and Handley 1979; Freestone and Hamilton 1980). The process of liquid immiscibility would

also place severe limitations on any attempt to use the whole-rock analyses to develop models of melt composition. The author is of the opinion that possible melt trends could only be developed using microprobe mineral analyses. The chemical data presented here is for comparative purposes only.

The pervasive metasomatism of the wall rocks as indicated by the development of sodium-iron amphiboles and pyroxenes and extensive development of biotite suggests considerable loss of alkalies and iron from the crystallizing carbonatite magma. This loss is analogous to the phlogopitization process by aqueous alkali-rich fluids, described by Gittins *et al.* (1975). The carbonatite rocks are, therefore, a residuum whose present composition does not represent carbonatite melt.

Alkalic rock norms (Appendix A, Table A-4) were calculated by the procedure of LeBas (1973). Statistical compositions of each map unit (Appendix A, Table A-5) were calculated using the methods of Nie *et al.* (1975).

## METAMORPHISM

The supracrustal rocks in proximity to the carbonatite are visually interpreted to be of middle greenschist facies rank of regional metamorphism. In traversing the enclosing rocks, the author at no time observed completely fresh rock unaffected by metasomatic and presumably thermal processes associated with carbonatite emplacement. It thus becomes difficult to determine regional metamorphic effects.

In examining the older literature on the Wawa supracrustal belt, dikes of lamprophyre-carbonatite appear to be very common in the now abandoned gold mines. These lamprophyre-carbonatite dikes are tentatively considered by the author to be consanguineous with the Firesand River Carbonatite Complex. Therefore, alkalic rock - carbonatite magmatism is pervasive within the immediate area of Wawa. The metasomatizing fluids associated with this alkalic event are likely to have been pervasive and thus sampling of the supracrustal rocks for petrogenetic study should be done with extreme care and caution.

The metasomatizing fluids in proximity to the Firesand complex resulted in a criss-cross network of dark green sodic amphibole and pyroxene filled fractures within the country rock. The more intensely altered rocks are green-black to black, and biotite and calcite may occupy the centre of the fractures. Hand specimens of relict fine-grained metavolcanics (?) with thick mantles of fine- to medium-grained biotite have been observed by the author and represent even more advanced metasomatism. A problem exists in distinguishing between samples representing extreme alterations and those representing phases of the complex, and unless relict fragments or textures can be observed, the distinction is impossible. Parsons (1961) interpreted the presence of altered gneissic rocks within the carbonatite in the southeastern portion of the body. These rocks are mica-rich, and lack visual evidence of relict textures similar to those of the enclosing wall rocks, however the author considers that Parsons' (1961) interpretation is likely correct. Spot checking of the waste rock dumps of a number of former gold mines south of Wawa indicates the presence of rocks presumably mapped as lamprophyre in the mine workings. These samples display both texture and mineralogy that are similar to some samples interpreted by the author and Parsons (1961) as being altered wall rock within the carbonatite complex. Other samples have been interpreted by the author as lithologically similar to, if not identical, to silicocarbonatite phases of magmatic origin found within the complex.

Thin section examination of rocks of the complex indicate that the intrusion itself is unmetamorphosed. Pleochroic haloes or zoning of the micas is common and fine-grained aggregates of zeolitic (?) alteration are thought to be after nepheline. Iron oxides, chlorite, serpentine, and other ill-defined alterations are present. These mineral zonations and alterations are considered by the author to be deuteric or autometasomatic and thus related to magmatic processes and not indicative of an independent metamorphic event.

In summation, the Firesand River Carbonatite Complex is enveloped in a halo of metasomatized rock that exceeds 1000 m in width. This halo represents a thermal-metasomatic (contact metamorphic) overprint of a regionally metamorphosed supracrustal sequence of possible middle greenschist to lower amphibolite facies rank. On the basis of mineralogy, the fenitizing fluid was initially iron- and sodium-rich (pyroxene and amphibole) and later became carbonate- and potassium-rich (carbonate, biotite filled fracture centres).

## STRUCTURAL GEOLOGY

### REGIONAL SETTING

The complex lies within the Wawa Subprovince immediately northwest of the Kapuskasing Subprovince of the Superior Province. The Kapuskasing Subprovince is characterized geophysically as a northeast-trending zone of gravity highs and pronounced linear aeromagnetic trends (Innes 1960; ODM-GSC 1970). This anomalous gravity zone has been interpreted as being a reflection of an upwarp in the Conrad discontinuity, caused by major regional faulting and the formation of a complex horst structure (Wilson and Brisbin 1965; Bennett *et al.* 1967). This prominent regional structure extends southward from the south end of Hudson Bay, becoming broader and more ill-defined as it approaches the Lake Superior Basin.

The Kapuskasing Subprovince (Kapuskasing Structural Zone) has been interpreted by Percival and Card (1983) as an upthrust tilted block represented by a northeast-striking, northwest-dipping fault. This faulting has exposed an oblique section of Archean crust 20 km thick (Percival and Card 1983). In the east, the faulting has placed high-grade rocks against low-grade rocks and to the west the high-grade rocks grade into low-grade rocks over a distance exceeding 100 km.

The Firesand River Carbonatite Complex is related to the extension of a fault or fault zone related to the Kapuskasing Structural Zone. Regional mapping as part of a program to examine the supracrustal rocks in the Wawa area indicates that the Firesand River Carbonatite Complex occurs at the intersection of two faults one of which is regional in extent and related directly to the Kapuskasing Structural Zone.

Immediately north of the Firesand River, the Wawa Lake Fault joins with the Hawk Lake Fault which in turn joins with the Manitowik Lake Fault (Sage 1987a,b). These three northeast-striking faults are one and the same and can be extended far beyond the limits of present mapping (Ayres *et al.* 1970). This regional fault is one of several within the Kapuskasing Structural Zone and while movement is strike-slip in the Wawa Lake section it cuts across regional stratigraphy in the Manitowik Lake section (Sage 1987a). Offset of the south contact of the Michipicoten greenstone belt with external granites on Manitowik Lake is left-lateral 2.8 km (Sage 1987a).

An inflection occurs at the east end of Wawa Lake where the Wawa Lake Fault joins the Hawk Lake Fault (Sage *et al.* 1982). A southwest-striking splay

splits from the main fault along Firesand River and has been named the Firesand Fiver Fault (Rupert 1975). The Firesand River Carbonatite was emplaced where the inflection occurs at the junction of the Wawa Lake and Hawk Lake Faults and the southwest striking Firesand River Fault (Sage 1987b, Sage *et al.* 1982).

### INTERNAL STRUCTURES

The complex is somewhat elongated in a northeast direction parallel to lithologic trends in the enveloping supracrustal rocks. The complex displays a strong, circular aeromagnetic anomaly (ODM–GSC 1963 a,b). The abundance of altered fragments of wall rock in the drill core examined by the author suggests that septa of wall rock are included in the carbonatite and that brecciation of the wall rock occurs along the contact. On the basis of generally radial or tangential trends of banding within outlying carbonatite dikes or contacts between the dikes and wall rocks, they are interpreted to be ring dikes or cone sheet–like intrusions. Layering in outcrop and weathered carbonatite generally dips vertically to subvertically. The strike is generally quite varied within relatively short distances. Layering in the diamond drill core examined (drilled at 45° to the horizontal) is approximately 45° to the core axis, probably also reflecting a vertical to subvertical dip. The banding very crudely outlines the general shape of the complex.

Parsons (1961, p.27) suggested the possibility of some faulting within the complex. Neither Parsons nor the author substantiated faulting of the complex.

Miarolitic cavities are common in some exposures of carbonatite bordering the large swampy area southeast of Blasko Lake. The cavities are lined with euhedral, hematite–coated carbonate crystals. Sharp, clear, transparent, bipyramidal quartz occurs in a number of cavities and one cavity contains euhedral, hematite–coated barite crystals nearly 1 cm in size. While most cavities are 1 cm in diameter or smaller, one cavity exceeds 4 cm in diameter. The author considers the cavities to be primary in origin and to have resulted from relatively low confining pressure of the intruding magma. The level of stratigraphic exposure of the Firesand River Carbonatite Complex is likely relatively high.

## MAGNETIC RESPONSE AND RADIOACTIVITY

The Firesand River Carbonatite Complex causes a prominent circular aeromagnetic anomaly (ODM–GSC 1963a,b). The Algoma Steel Corporation completed a ground magnetic survey over the body which outlined its circular nature and arcuate pattern of its lithologic units. The dolomite core of the body is represented by a magnetic low contrasting with the magnetic high over the calcite border.

Parsons (1961, p.29) reported maximum radioactivity of several times background over most of the complex. Parsons reported no correlation of niobium mineralization and radioactivity at the Morrison showing (location "B").

During the present project, a number of old trenches and weathered outcrops were spot checked with a scintillometer. Radioactivity locally is up to 6 or 7 times background and appears to be caused principally by thorium even though uranium is present. The complex has never been thoroughly prospected for uranium mineralization.

## RECOMMENDATIONS FOR FUTURE STUDY

Ms. S. Teal completed an M.Sc. thesis on the complex and has provided valuable data on mineral chemistry. Additional work on the mineralogy of the complex is

warranted. If additional drilling of the body is undertaken, much additional chemical, petrographic and petrologic study is warranted. Data is meagre or absent regarding the rauhaugite (dolomite) core of the body and much work remains to be done on this portion of the body.

The rauhaugite core at the Firesand Complex is likely the largest and perhaps best developed dolomitic unit within Ontario carbonatite complexes.

If additional surface mapping is undertaken for mineral exploration, a grid at a maximum line spacing of 70 m should be used to maximize the location of outcrop. Outcrops are small, deeply weathered and distributed in an arcuate manner. Mapping should include sampling all outcrops and all types of outcrop; i.e., solid outcrop, slump and regolith along and between grid lines.

# Economic Geology

The complex is known to contain widespread low-grade niobium mineralization and the results of the efforts by the Algoma Steel Corporation Limited to outline economic mineralization have been summarized by Parsons (1961). The International Minerals and Chemical Corporation made an unsuccessful attempt to locate residual accumulations of apatite even though apatite is an abundant minor constituent within phases of the intrusion. In 1972, the outer rim of the complex was drilled by the Algoma Steel Corporation Limited in hopes of delineating a zone of calcite which could be used in their sinter plant in Wawa. During the 1977 field season the author, J.A. Robertson, Minerals Deposit Section of the Ontario Geological Survey, and V. Ruzicka, Uranium Resource Evaluation Section, Geological Survey of Canada, checked a number of outcrops and trenches with a scintillometer to determine if uranium was present. The widespread presence of uranium was indicated, but in relatively small quantities. The author did not consider the scintillometer results to warrant follow-up assays. The author considers that barite found in float has no economic significance. Table 9 is a summary of drilling completed on the complex.

## PROPERTY DESCRIPTIONS

### Algoma Steel Corporation Limited [1950-53, 1971-72]

In 1950 the complex was staked by Algoma Ore Properties Limited to check its iron potential. The company completed a geological and dip needle survey of the complex at this time. In 1951, the company completed 16 diamond drill holes totalling 2531 m and some limited trenching, and in 1952, 67.5 m of pack sack drilling. In 1953, niobium was recognized in the Firesand River Carbonatite Com-

**TABLE 9. DRILLING COMPLETED ON THE FIRESAND RIVER CARBONATITE COMPLEX, 1951-1976.**

| Company | No. of Holes | Footage | Date | Purpose |
|---|---|---|---|---|
| Algoma Steel Corp. Ltd.[1] | 16 | 8,437' (2531 m) | 1951 | Iron, niobium |
| | 6 | 225' (67.5 m) | 1952 | Assessment |
| | 6 | 3,725' (1117.5 m) | 1953 | Niobium |
| | 8 | 2,391' (717 m) | 1972 | Calcite |
| Gibson Property[2] | 3 | 186' (55.8 m) | 1925 | Iron |
| International Minerals and Chemical Corp.[3] | 3 | 380' (114 m) | 1976 | Residual apatite |

1. Logs for diamond drill holes 21, 22 and packsack hole 1 are absent from Ministry and Corporate files.
2. Log for hole No. 1 not present in corporate files. Footage from Collins and Quirke (1926).
3. Drilling was reverse circulation to test for residual apatite accumulations on carbonatite surface.

plex and core from the original 16 holes was tested for niobium content. An additional 6 diamond drill holes were completed for 1117.5 m in search of niobium (personal communication, J.V. Huddart, Exploration Manager, Algoma Steel Corporation Limited, 1977). This work disclosed the presence of erratic niobium mineralization. Assay data indicated that the niobium ranged from trace to 0.62%, but most assays returned less than 0.10% (personal communication, J.V. Huddart, 1977). Parsons (1961, p.30) reported the following niobium assays:

| $Nb_2O_5$ | Hole No. | Footage |
|---|---|---|
| 0.30% | 11 | 780-830' (238-253 m) |
| 0.24% | 18 | 17-70' (5-21 m) |
| 0.24% | 19 | 160-190' (49-58 m) |
| 0.25% | 20 | 540-680' (154-207 m) |

The Algoma Steel Corporation has donated to the Ministry the drill logs and assays for the drilling completed during this period of time. The data are too voluminous to present here, but may be consulted at the Assessment Files Research Office of the Ontario Geological Survey.

In 1970 the Algoma Steel Corporation Limited investigated the carbonate potential of the complex, hoping to use the calcite-rich areas of the body as a source of lime for its sinter plant in Wawa. The complex was sampled at surface, a grid re-established, and a magnetometer survey completed. In 1972 the company completed 8 diamond drill holes totalling 717 m to test the calcite-bearing rim of the complex. The carbonate proved too high in phosphorus, silica and magnesium for the requirements of the sinter plant (Khan 1972b, p.14).

Parsons (1961, p.30) described two locations within the Algoma Steel Corporation Limited property which contain niobium mineralization. The locations are indicated on Figure 3 (Chart A, back pocket). These zones could not be examined at present without doing considerable clearing at the locations. Parsons (1961, p.30) described the locations as follows:

> "*Zone C:* Surface sampling gave results of up to 0.52% $Nb_2O_5$ in calcite carbonatite outcrops and rubble areas. ... small, well-formed, light-brown octahedra of pyrochlore occur in a disintegrated calcite carbonatite exposure, with magnetite crystals of similar size and shape, and apatite and biotite.
>
> "*Zone D:* Surface sampling of the dolomitic core area by Algoma Ore Properties revealed only very low niobium content, except at Location D. Here, assays up to 1.32% $Nb_2O_5$ have been obtained in a very rusty outcrop."

### Gibson Property [1922-1925]

Hematite float was discovered near Firesand Creek by Angus Gibson of Sault Ste. Marie in the fall of 1922 (Collins and Quirke 1926). The hematite showings were staked and considerable work was completed in the following years. Private records of the Algoma Steel Corporation Limited indicate the completion of approximately 300 m of trenching on claims 3263 and 3262. Three diamond drill holes were completed totalling at least 55 m. This work was likely done on claim 3250. Logs for this drilling are incomplete. Sample numbers for core from hole number 3 indicate that it was completed to a depth of at least 69.3 m even though only 12.3 m were recorded (private records, Algoma Steel Corporation Limited). Collins and Quirke (1926, p.81) reported two assays from this work which are given in Table 10. This work proved unsuccessful in delineating an economic iron deposit.

**TABLE 10. IRON ASSAYS FOR SAMPLES FROM THE GIBSON PROPERTY, REPORTED BY COLLINS AND QUIRKE (1926).**

| | I | II |
|---|---|---|
| Fe | 25.60 | 55.5 |
| $SiO_2$ | 1.98 | 1.00 |
| CaO | 14.58 | 0.96 |
| Loss on ignition | 24.58 | 12.16 |

I. Fresh core.
II. Oxidized material across 17 feet of surface.

### International Minerals and Chemical Corporation [1976]

Upon reaching a verbal agreement with the Algoma Ore Division of Algoma Steel Corporation Limited, the International Minerals and Chemical Corporation completed three reverse circulation holes totalling 114 m testing for residual apatite accumulations. This work was done in 1976 and failed to disclose residual apatite (G. Erdosh, Geologist, International Minerals and Chemical Corporation, Libertyville, Illinois, personal communication). Prior to drilling, the company collected a suite of samples at surface for assaying for phosphorus. These samples varied from 0.23 to 4.95% phosphorus (personal communication, G. Erdosh). Selected samples of weathered carbonatite encountered in this drilling returned 2.0% or less $P_2O_5$ (Erdosh 1976).

### Morrison et al. Claims [1958–1959?]

Data regarding work by Morrison *et al.* is not present within the Assessment Files Research Office of the Ontario Geological Survey. The present information is taken from Parsons (1961, p.30– 32)(Figure 4).

"Nine claims on the northwest flank were held jointly by N. and R. Morrison, F. Krimpotich, and W. Jarvis of Wawa. Their work consisted of prospecting and trenching, which has

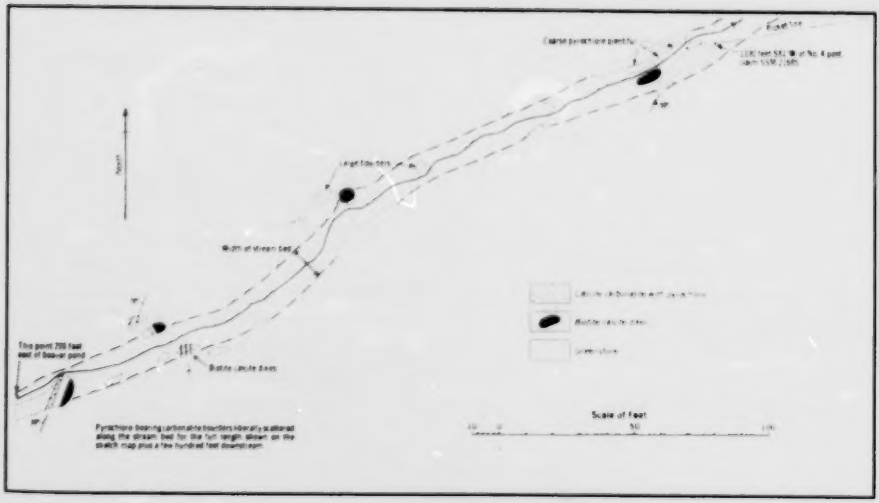

**Figure 4.** ***"Main pyrochlore showing on Morrison et al. claims..." from Parsons (1961).***

increased the amount of carbonatite exposed and disclosed showings with visible pyrochlore. The two main showings are marked as locations A and B on the geological map [Figure 3, Chart A].

"The showing at Location A occurs in a trench on the east side of hill, 300 feet east and 100 feet north of No. 4 post of surveyed claim S.S.M.21664. Here, typical, crumbly calcite carbonatite is exposed across a 20-foot width. Assays of up to 0.29% $Nb_2O_5$ have been obtained across this width. Small amber-coloured octahedra of pyrochlore are visible in a more solid rib of carbonates. The showing at Location B occurs in a creek bed, 1100 feet S.81° of the No. 4 post of surveyed claim S.S.M.21685. It has been well exposed by a recent wash-out along the creek. The geology is shown in [Figure 4]. Here, pyrochlore cyrstals up to 1/4 inch across, with magnetite crystals up to 3/4 inch in diameter, and rosettes of actinolite, are particularly plentiful along the northwest side of the exposure.

"The exposed width of this calcite carbonatite is 15 feet, and its southeast contact with the greenstones is not exposed. In view of the size and uneven distribution of the pyrochlore, close drilling or bulk sampling would be required to obtain a reliable estimate of the niobium content.

"Pyrochlore-bearing carbonatite boulders are plentiful for 300 feet upstream and 200 feet downstream along the general strike of the zone."

### Pango Gold Mines Limited [1970]

Pango Gold Mines Limited at one time controlled two claim blocks, one along the western and northwest flank of the intrusion in McMurray Township and a second grouping in Lastheels Township along the northeast flank of the Firesand River Carbonatite Complex. The company completed a magnetometer survey and geological mapping over its holdings. These claim blocks covered the former holdings of Morrison *et al.* and some prospecting was completed in the general area of the former showings.

## RECOMMENDATIONS TO THE PROSPECTOR

Under economic conditions at the time of writing, the complex has been suitably tested for niobium but may warrant re-examination in the future. The work by the International Minerals and Chemical Corporation has diminished the potential for residual apatite deposits but areas in the southern and western portions of the complex may still have possibilities. While apatite and niobium mineralization are present, previous work suggests that any additional occurrences discovered are likely to be relatively small. Uranium and thorium are present within the complex but the quantities appear to be low and erratic and are presently not encouraging as a target for exploration.

The hematite found within the core of the complex is a relatively thin residual capping which is not likely of sufficient volume to warrant its extraction for iron. Work by the Algoma Steel Corporation Limited indicated that the calcite-rich rim rocks contain too many impurities to be used as flux in the local sinter plant.

The dolomitic core of the St. Honôré carbonatite, Québec, contains up to 4.5% combined rare earths (Gagnon 1979). This dolomitic core may be similar in composition to the dolomitic core found at the Firesand River Carbonatite Complex. The Firesand River Carbonatite Complex has never been examined for rare earth mineralization, therefore, the dolomitic core warrants testing to determine its rare earth metal content.

# Appendix A — Petrographic Descriptions, Chemical Analyses, Normative Compositions, and Statistical Compositions of Lithologic Units of the Firesand River Carbonatite Complex.

TABLE A-1. PETROGRAPHIC AND FIELD DESCRIPTIONS OF WHOLE-ROCK SAMPLES* FROM THE FIRESAND RIVER CARBONATITE COMPLEX.

**Reference No. 1222**
**Sample No. FS-2A5**

*Phlogopite and magnetite-bearing, clinopyroxene silicocarbonatite.*

Field Description. Fine to medium grained. Weathered and fresh surfaces are grey. Sample displays some banding. The sample was taken from outcrop next to stream bed. Map unit 7b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic. Phlogopite forms anhedral irregular grains commonly with pale yellowish brown cores (phlogopite) and reddish brown rims (biotite). Phlogopite and carbonate are intergrown implying simultaneous crystallization. Phlogopite encloses pyroxene and may rim magnetite. Traces of apatite occur as subhedral to euhedral prismatic crystals. Clinopyroxene forms anhedral to subhedral irregular grains with poikilitic inclusions of apatite and magnetite. Magnetite is anhedral and disseminated. Carbonate is anhedral, interlocking, and interstitial. One area of sample is altered to a fine grained, turbid mass of limonite and chlorite. Some pyroxene is possibly undergoing uralitization to fibrous amphibole.

**Reference No. 1223**
**Sample No. FS-2C1**

*Perovskite, magnetite, amphibole, phlogopite silicocarbonatite.*

Field Description. Fine grained, massive, equigranular. Carbonate tends to occur in capillary veinlets. Weathered and fresh surfaces are black. The sample was taken from outcrop next to stream bed. Map unit 7b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Perovskite forms anhedral to subhedral grains disseminated throughout, commonly in association with magnetite. Magnetite forms anhedral to subhedral grains, disseminated throughout. Several isolated patches consist of fine-grained magnetite, serpentine, chlorite alteration. Amphibole forms colourless, anhedral to subhedral, acicular grains; some grains have ragged ends interlocking with each other and phlogopite. It locally encloses some magnetite grains. Phlogopite with very pale pleochroism forms tabular, anhedral grains interlocking with amphiboles. Some larger grains have turbid, nearly opaque cores due to magnetite inclusions. Carbonate is anhedral, interstitial.

**Reference No. 1224**
**Sample No. FS-2D1**

*Fenitized mafic metavolcanics.*

Field Description. Fine grained, equigranular, massive. Weathered and fresh surfaces are black. Carbonate occurs along fractures in outcrop. Map unit 1a.

Petrographic Description. Very fine grained, massive, equigranular, allotriomorphic with serrate grain boundaries. Amphibole is very fine grained, prismatic and pale green to colourless.

**Reference No. 1225**
**Sample No. FS-4B2**

*Olivine-, apatite- and phlogopite-bearing, magnetite, olivine sovite.*

Field Description. Fine to medium grained. Weathered and fresh surfaces are grey. The sample was taken from outcrop next to stream bed. Map unit 7a.

**Reference numbers for outcrop samples are plotted on Figure 3 (Chart A). Locations of drill core samples are indicated on Figure 3 by the drillhole number.*

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Apatite forms anhedral, rounded grains which are disseminated. Magnetite forms subhedral crystals disseminated throughout. Some grains enclose carbonate. Carbonate forms an anhedral, interlocking mosaic. Pyrochlore forms small reddish brown crystals which are subhedral and located on the edges of magnetite crystals. Several isolated grains occur in carbonate. Hematite(?) occurs in traces as tiny needle-like crystals. Phlogopite forms anhedral to subhedral grains pleochroic in pale light yellow-brown to deep reddish brown. Some phlogopite may be after olivine. Perovskite occurs in traces on edges of magnetite grains. Olivine forms anhedral rounded grains with serpentine along curved cracks and with kelyphitic rims. Apatite is partially enclosed in several grains.

**Reference No. 1226**
**Sample No. FS-7**

*Sovite.*

Field Description. Medium to coarse grained, massive, inequigranular-porphyritic-seriate. Weathered and fresh surface are white. Anhedral carbonate phenocrysts are up to 4 cm. Rare euhedral magnetite crystals occur within weathered carbonate. The rock is nearly pure calcite. The exposure consists of a bald clear area, where the ground is a loose aggregate of carbonate rhombs and an occasional resistant clot of sovite. Map unit 5a.

Petrographic Description. Medium grained, massive, equigranular, allotriomorphic with curved to lobate grain boundaries. Carbonate forms an interlocking mosaic of anhedral grains.

**Reference No. 1227**
**Sample No. FS-9**

*Apatite and magnetite-bearing rauhaugite.*

Field Description. Fine grained, equigranular, massive. The rock weathers to a hematite and limonite coating. Fresh surface is mottled grey and yellow-brown. The sample was taken from bottom of an old trench. Map unit 6a.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to lobate grain boundaries. Apatite forms subhedral to euhedral crystals disseminated throughout. Magnetite encloses apatite and turbid carbonate. Some grains are partially skeletal. Carbonate is turbid probably from dusty hematite or magnetite, and shows the odd rhombohedral crystal face. Carbonate has interlocking curved to lobate grain boundaries.

**Reference No. 1228**
**Sample No. ST-2A**

*Magnetite, amphibole sovite.*

Field Description. Very fine grained, rusty weathering. Limonite occurs along fracture surfaces. Fresh surfaces are brown. Map unit 5b.

Petrographic Description. Fine grained, massive equigranular, allotriomorphic with straight to curved grain boundaries. Magnetite is anhedral, disseminated. A brown alteration forms irregular splashes imparting a mottled appearance to the rock. Limonite may be after magnetite or the carbonate may be ferruginous and limonite forms acicular ragged anhedral grains. Carbonate forms an anhedral, interlocking mosaic of interstitial grains.

**Reference No. 1229**
**Sample No. ST-5**

*Phlogopite-bearing, apatite sovite.*

Field Description. Fine to medium grained, massive, equigranular. Weathered surfaces are brownish-white, fresh surfaces grey-white. Traces of limonite occur along some fractures. Map unit 5a.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Carbonate forms an anhedral, interlocking mosaic. Apatite forms anhedral, rounded to rounded-elongate crystals. Apatite grains tend to cluster. Phlogopite forms anhedral to subhedral, tabular booklets. Pleochroism is pale yellow-brown to brown.

**Reference No. 1230**
**Sample No. ST-10A**

*Magnetite, amphibole, phlogopite-biotite silicocarbonatite.*

Field Description. Fine grained, massive, equigranular, silicocarbonatite. Weathered surfaces are brown, fresh surfaces black. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Phlogopite-biotite forms tabular grains, pleochroic from light yellow-brown to reddish brown. Pleochroism occurs in ribbons across grain with reddish brown colour generally occurring on margins of grain. Cores of biotite-phlogopite grains tend to be somewhat turbid from dusty magnetite. Phlogopite-biotite grains interlock with amphibole. Amphibole is subhedral to euhedral and forms an interlocking jackstraw pattern. Grains are acicular and occasionally include magnetite. Magnetite is anhedral to subhedral, disseminated and tends to occur as aggregates of several grains. Carbonate is anhedral, interlocking, and interstitial.

**Reference No. 1231**
**Sample No. ST-10D**

*Carbonate, magnetite, amphibole, phlogopite-biotite silicocarbonatite.*

Field Description. Fine to medium grained, equigranular. The rock contains large irregular blebs of white carbonate up to 2 or 3 cm. Margins of clots display abundant tabular plates of biotite up to 5 mm in length. Carbonate blebs were removed from the samples before analysis. Clots may be segregation or immiscibility features. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Phlogopite-biotite forms anhedral, tabular grains, pleochroic from light yellow-brown to dark reddish brown. Pleochroism forms ribbons across grains, but generally occurs along margins or as rims on grains. Compositional zoning and/or banding are evident. It contains poikilitic magnetite and amphibole. Amphibole forms anhedral to euhedral, acicular, colourless crystals, forming an interlocking jackstraw pattern. Magnetite is anhedral to euhedral, disseminated, and some grains tend to occur as aggregates. Carbonate forms anhedral, interstitial grains.

**Reference No. 1232**
**Sample No. ST-11**

*Amphibole, phlogopite-biotite silicocarbonatite.*

Field Description. Fine grained, massive, equigranular. Weathered surfaces are brownish-black, fresh surfaces black to brownish-black. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Phlogopite-biotite forms tabular grains with some tabular magnetite grains enclosed parallel to (001) cleavage. There is some bending of (001) cleavage. Grains are zoned from pleochroic light yellow-brown cores to darker reddish brown rims. Biotite occurs as a fine grained, anhedral mass throughout sample; it commonly displays a fibrous habit. Amphibole forms turbid, anhedral, fibrous grains interlocking with phlogopite-biotite, biotite, and other amphibole. Minor limonite occurs as splashes throughout the thin section. Traces of sphene are present.

**Reference No. 1233**
**Sample No. ST-20**

*Magnetite, amphibole, apatite sovite.*

Field Description. Fine to medium grained, equigranular, weakly banded. Weathered surfaces are pale brown, fresh surfaces mottled light and dark grey. Map unit 7a.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Magnetite is anhedral, generally fine grained to dusty, and disseminated throughout. Traces of perovskite and limonite are present. Apatite forms euhedral, rounded to rounded-elongate grains, which locally contain poikilitic magnetite.

**Reference No. 1234**
**Sample No. ST-21**

*Apatite-bearing, carbonate, magnetite, garnet, phlogopite ijolite.*

Field Description. Medium grained, massive, equigranular. Weathered and fresh surfaces are mottled green and black. Map unit 7b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Some chlorite occurs as anhedral, greenish-brown fibrous grains, with possibly some serpentine. Chlorite is possibly after olivine. Dusty magnetite is present. Nepheline forms fresh to altered, anhedral grains, enclosing rounded, anhedral, colourless, random oriented grains of pyroxene. Altered nepheline is locally a turbid pale brown. The pyroxene and nepheline may have been closely contemporaneous in crystallization. Clinopyroxene is anhedral, colourless, stubby or equant and diopsidic. Phlogopite forms tabular grains; it is pleochroic in light yellow, and encloses magnetite, carbonate, and garnet. Garnet is

a pale brown to dark reddish brown, anhedral to subhedral, and scattered throughout samples. Locally it encloses apatite and phlogopite. Apatite is anhedral to subhedral forming rounded to rounded-elongate prisms. Magnetite is anhedral and disseminated. Carbonate is anhedral and interstitial.

**Reference No. 1235**
**Sample No. ST-26**

*Magnetite, olivine, perovskite, phlogopite, amphibole silicocarbonatite.*

Field Description. Fine grained, massive, equigranular. Weathered surfaces are brownish-black, fresh surfaces black to brownish-black. Map unit 7a.

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Olivine forms rounded, anhedral grains with traces of chondrodite and dusty magnetite along edges. Perovskite forms anhedral to euhedral, disseminated, turbid grains which are weakly anisotopic. Magnetite is anhedral to subhedral and disseminated throughout. Phlogopite forms anhedral, ragged grains enclosing magnetite, perovskite and amphibole. Several grains in contact with carbonate have nearly colourless rims. Amphibole forms acicular, fibrous, interlocking, anhedral grains; some may be after olivine. Possibly traces of clinopyroxene are present. Carbonate is anhedral and interstitial.

**Reference No. 1236**
**Sample No. ST-34**

*Plagioclase, magnetite, amphibole, biotite silicocarbonatite.*

Field Description. Fine grained, massive, equigranular. Weathered surfaces are brownish-black to black, fresh surfaces black with white mottling from carbonate. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Plagioclase (albite-oligoclase) forms anhedral, interstitial grains interlocking with biotite, amphibole and magnetite. It encloses carbonate and amphibole. Amphibole forms ragged, anhedral grains with mottled extinction, and extinction angles variable from parallel to greater than 20°. Possible traces of pyroxene are present. Grains are turbid, ragged and colourless to pale green. Sphene forms anhedral to subhedral grains. Some are crudely wedge-shaped. Biotite forms ragged, anhedral, brown grains enclosing magnetite, amphibole and sphene. Magnetite is anhedral and disseminated. Carbonate is anhedral and interstitial. Presence of feldspar implies possible contamination.

**Reference No. 1237**
**Sample No. ST-62**

*Carbonate, biotite ijolite.*

Field Description. Fine to medium grained equigranular, massive. Weathered surfaces are brown, fresh surfaces mottled black and white. White colour is caused by carbonate. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Nepheline forms anhedral to euhedral, stubby crystals; some grains display extensive alteration and are interlocking with pyroxene. Clinopyroxene is subhedral to euhedral, green aegirine-augite. Biotite forms reddish brown anhedral grains; it may partially enclose pyroxene and nepheline. Carbonate is anhedral and interstitial. Minor accessory sphene and magnetite are present.

**Reference No. 1238**
**Sample No. ST-70**

*Biotite-bearing sovite.*

Field Description. Fine grained, weakly foliated. Very fine grained magnetite is disseminated. Weathered surfaces are brown, fresh surfaces mottled grey to buff. Traces of limonite occur along fractures. Map unit 5a.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Minor fine-grained, subhedral, reddish brown grains of biotite are present. Traces of anhedral magnetite are present. Carbonate forms a mosaic of anhedral interlocking grains.

**Reference No. 1239**
**Sample No. ST-76**

*Amphibole, garnet, nepheline, biotite silicocarbonatite.*

Field Description. Fine grained, equigranular, massive, well banded. Banding is due to variation in mafics and carbonate. A large sample was analysed and should be representative of total rock. Map unit 7b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Sphene forms subhedral grains, crudely wedge-shaped in form. Nepheline forms anhedral grains interlocking with biotite and amphibole. Carbonate may be enclosed in small amounts. Garnet forms anhedral, ragged grains of deep reddish brown colour. Some nepheline and carbonate are partially enclosed. Amphibole forms anhedral, ragged, prismatic grains. Biotite forms anhedral, tabular, brown to reddish brown grains interlocking with nepheline and amphibole. Carbonate forms anhedral, interstitial grains.

**Reference No. 1240**
**Sample No. ST-81**

*Magnetite, perovskite, amphibole, phlogopite-biotite silicocarbonatite.*

Field Description. Fine grained, massive, equigranular. Secondary carbonate occurs along fractures. Weathered surfaces are brown, fresh surfaces brownish-black. Map unit 7b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Phlogopite-biotite forms anhedral, somewhat ragged grains pleochroic in light yellow-brown; some grains are zoned and have narrow reddish brown (biotitic) rims. It poikilitically encloses magnetite and perovskite. Amphibole forms anhedral, acicular, ragged grains with mottled extinction. Perovskite forms anhedral to euhedral grains that are weakly anisotopic. Magnetite is anhedral to subhedral, disseminated. Carbonate is anhedral, interstitial.

**Reference No. 1241**
**Sample No. ST-84**

*Amphibole, biotite silicocarbonatite.*

Field Description. Fine to medium grained, massive. Weathered and fresh surfaces are black. Fresh surfaces are mottled with white from carbonate. Map unit 7b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms anhedral, crudely rounded to rounded-elongate grains. Biotite forms brown, tabular, anhedral, irregular grains, which locally enclose carbonate, magnetite and amphibole. Large grains are zoned from dark brown cores to reddish brown rims. Sphene forms subhedral wedge-shaped crystals. Amphibole forms anhedral, acicular, ragged grains, colourless to pale green. Magnetite is anhedral and disseminated. Carbonate is anhedral and interstitial.

**Reference No. 1242**
**Sample No. ST-86**

*Garnet, carbonate, phlogopite ijolite.*

Field Description. Medium grained, massive, equigranular. Weathered surfaces are brownish-black, fresh surfaces black mottled with white carbonate. Garnet and biotite common. Map unit 7b.

Petrographic Description. Fine to medium grained, inequigranular-seriate, massive, allotriomorphic with curved to straight grain boundaries. Nepheline and possibly former nepheline is anhedral. Fresher nepheline is oikiocrystic with respect to pyroxene. Large irregular patches of very fine-grained material may be a mixture of analcite(?) and zeolites after nepheline. Some apatite is enclosed in fresh nepheline. Garnet occurs as irregular, anhedral, poikiloblastic grains enclosing biotite, carbonate, magnetite and apatite. Some garnet appears to rim some phlogopite grains. Phlogopite forms anhedral, tabular grains of pale light yellow to greenish-brown colour and encloses carbonate and garnet. Clinopyroxene is a colourless, anhedral, irregular mineral. Some grains may be enclosed in nepheline. Magnetite is anhedral and rims may display a very fine-grained mixture of phlogopite and garnet. Apatite occurs as anhedral, crudely rounded to prismatic grains. The rock appears to be deuterically altered.

**Reference No. 1243**
**Sample No. ST-97**

*Magnetite, plagioclase, amphibole silicocarbonatite.*

Field Description. Fine grained, massive, equigranular. Weathered surfaces are brownish-black, fresh surfaces black and mottled with white from carbonate. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Plagioclase (albite-oligoclase) forms anhedral, irregular grains, dusted with inclusions of carbonate and possibly epidote(?). Amphibole forms anhedral, colourless grains with acicular to fibrous habit and mottled extinction. Phlogopite forms anhedral,

ragged grains with pale yellow-brown cores and dark reddish brown (biotitic) rims, which contain poikilitic magnetite. There is weak bending of (001) cleavage. Tabular lensoid inclusions of magnetite occur parallel to (001) cleavage in some grains. Magnetite is anhedral, disseminated, and common in phlogopite. Carbonate is anhedral and disseminated. The presence of feldspar suggests that the rock may be a hybrid.

**Reference No. 1244**
**Sample No. F-59**

*Magnetite- and phlogopite-bearing, apatite, amphibole sovite.*

Field Description. Fine to medium grained, massive, equigranular. Weathered surfaces are grey and weakly iron stained. Fresh surfaces are grey. Map unit 5c.

Petrographic Description. Fine to medium grained, massive, equigranular, hypidiomorphic. Amphibole forms acicular, subhedral to euhedral crystals with pale green pleochroism. Some grains occur as tuffs of needle-like crystals. Carbonate grains form an anhedral, interlocking mosaic. Magnetite occurs as anhedral, disseminated grains which may enclose apatite. Phlogopite forms anhedral irregular grains. Some grains are zoned from light yellow-brown cores to dark reddish brown rims. Apatite forms rounded to rounded-elongate, anhedral grains.

**Reference No. 1245**
**Sample No. F-59C**

*Amphibole, garnet, pyroxene, phlogopite silicocarbonatite.*

Field Description. Fine to coarse grained, massive, inequigranular-seriate. Large subhedral grains of garnet are evident in outcrop. Map unit 5c.

Petrographic Description. Fine to coarse grained, inequigranular-seriate, allotriomorphic with curved to straight grain boundaries. Carbonate is anhedral and interstitial. Reddish brown masses, which are anhedral in form, may be iddingsite after olivine(?). Garnet is anhedral and dark reddish brown; it may enclose apatite, phlogopite and magnetite. Clinopyroxene forms anhedral, colourless grains, which may enclose blebs of carbonate. Large grains are poikiloblastic and contain reddish brown, rounded grains, possibly olivine altered to iddingsite. Some colloform texture is present in the reddish brown material. Phlogopite forms anhedral, tabular grains enclosing apatite and carbonate. Traces of reddish brown rims occur on some grains. Amphibole forms anhedral, prismatic ragged grains, which locally enclose apatite and rounded grains of clinopyroxene. It is intergrown with carbonate in optically continuous grains implying nearly simultaneous crystallization. Amphibole is pleochroic in pale green to green. Apatite is minor. It occurs as anhedral, subrounded to prismatic grains.

**Reference No. 1246**
**Sample No. F-72**

*Quartz-bearing, apatite sovite.*

Field Description. Fine to medium grained, equigranular. Weathered surfaces have some limonitic staining. Fresh surfaces are pink to pinkish-brown. Map unit 5b.

Petrographic Description. Fine to medium grained, massive, equigranular, hypidiomorphic. Quartz is anhedral, and interstitial to carbonate and apatite grains. Amoeboid to irregular angular grains display wavy extinctions. Quartz formed late in the order of crystallization; it does not appear to be xenocrystic but to be a late stage deuteric(?) mineral. Apatite forms subrounded, anhedral to euhedral grains. Some are elongate in outline. Crystals cut normal to 'C' crystallographic axis display variable birefringence from centre outwards implying possible compositional variation. Traces of anhedral disseminated magnetite are present. Carbonate forms an interlocking mosaic of anhedral grains. One large grain of carbonate contains rhombohedral crystals of a second carbonate, possibly dolomite.

**Reference No. 1247**
**Sample No. F-112**

*Apatite, pyroxene, biotite sovite.*

Field Description. Fine grained, massive, equigranular biotite. Weathered surfaces have a thin coating of limonite, fresh surfaces are grey flecked with black. Map unit 7a.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Biotite forms deep reddish brown, tabular grains interlocking with pyroxene. Rarely some grains have light brown cores and dark reddish brown rims. Clinopyroxene is turbid, anhedral to subhedral, pleochroic green aegirine-augite. Apatite forms

anhedral, subrounded grains disseminated throughout. Carbonate forms an interlocking mosaic of anhedral grains.

**Reference No. 1248**
**Sample No. F-148**

*Sovite.*

Field Description. Medium to coarse grained, massive, equigranular-seriate. Rock tends to be porphyritic with massive larger grains of white carbonate. Weathered surfaces have a secondary carbonate coating. Fresh surfaces are mottled pink and white. Map unit 5a.

Petrographic Description. Fine to medium grained, massive, equigranular, allotriomorphic with straight grain boundaries. Carbonate forms an interlocking mosaic of anhedral grains. Traces of quartz, apatite, limonite and biotite are present.

**Reference No. 1249**
**Sample No. F-176**

*Quartz sovite.*

Field Description. Medium grained, equigranular. Weathered surfaces are pink to slightly rusty, fresh surfaces grey. Map unit 5b.

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Quartz forms anhedral, interstitial aggregates of unstressed grains lying between carbonate grains. Carbonate is anhedral to subhedral in form with sharp rhombohedral crystal faces projecting into quartz aggregates.

**Reference No. 1250**
**Sample No. F-179**

*Quartz sovite.*

Field Description. Fine to medium grained, massive, equigranular. Weathered surfaces are covered with secondary carbonate. Fresh surfaces are pink. Map unit 5b.

Petrographic Description. Fine to medium grained, massive, equigranular, hypidiomorphic. Quartz forms anhedral aggregates of grains interstitial to carbonate. Carbonate forms an anhedral to euhedral, interlocking mosaic of grains. Sharp rhombohedral crystal faces project into quartz. Traces of apatite, limonite and biotite are present. At high magnification quartz may display inclusion trains of very tiny bubbles. Quartz is clear and unstressed. Dusty limonite occurs on quartz carbonate grain boundaries. Quartz is a late-stage crystallization feature, perhaps at the hydrothermal stage of carbonatite formation.

**Reference No. 1251**
**Sample No. F185B**

*Amphibole- and magnetite-bearing biotite sovite.*

Field Description. Fine grained, equigranular. Weathered surfaces are rusty, fresh surfaces grey-black to greenish-black. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Biotite forms anhedral, tabular, dark reddish brown grains. Cores of some grains may be slightly lighter brown than rims. Amphibole is euhedral, acicular, and pleochroic green. Magnetite is anhedral and disseminated; some grains are nearly skeletal, and are enclosed by carbonate and biotite.

**Reference No. 1252**
**Sample No. F-195**

*Magnetite-bearing, biotite, pyroxene sovite.*

Field Description. Fine to medium grained, massive, equigranular. Weathered surfaces are rusty, fresh surfaces black. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, hypidiomorphic. Magnetite forms anhedral grains disseminated throughout. It is locally enclosed in biotite and rarely encloses pyroxene. Clinopyroxene is an anhedral to euhedral aegirine-augite with poikilitic inclusions of biotite and carbonate. Biotite forms tabular, irregular, reddish brown grains interlocking with pyroxene. It locally encloses pyroxene or is poikilitic in pyroxene. Carbonate may also be enclosed. Several highly altered grains of a very fine-grained, fibrous mineral are possibly after nepheline. Some altered patches appear mottled with reddish brown biotite.

**Reference No. 1253**
**Sample No. F-208**

*Amphibole(?)-bearing, apatite sovite.*

Field Description. Fine to medium grained, massive, equigranular-seriate. Weathered surfaces are coated with secondary carbonate. Fresh surfaces are white with black spots. Map unit 5a.

Petrographic Description. Fine to coarse grained, massive, inequigranular-seriate, allotriomorphic with curved to straight grain boundaries. Apatite forms rounded to subrounded, anhedral grains, which are scattered throughout and form small aggregates. Amphibole(?) forms intensely turbid, anhedral, pleochroic grains. Grains are intensely altered, possibly after pyroxene. Carbonate forms an anhedral, interlocking mosaic of anhedral grains.

**Reference No. 1254**
**Sample No. F-236C**

*Magnetite, barite rauhaugite.*

Field Description. Fine grained, equigranular. Weathered surfaces have a hematitic coating. Fresh surfaces are mottled grey and yellow-brown. Map unit 6a.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Barite forms anhedral to euhedral blades and tends to occur in aggregates. Magnetite is anhedral to euhedral in form, disseminated; a reddish brown (limonite?), turbid alteration occurs along margins of some grains. Some crudely skeletal grains may contain carbonate.

**Reference No. 1255**
**Sample No. F-316**

*Sovite.*

Field Description. Fine grained, equigranular. Weathered surfaces are pink to faintly rusty. Fresh surfaces are buff to pale pink. Map unit 5b.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Carbonate forms an interlocking mosaic of anhedral grains. Traces of limonite, magnetite and quartz are present.

**Reference No. 1256**
**Sample No. F-341**

*Magnetite, perovskite, biotite sovite.*

Field Description. Fine grained, equigranular. Weathered surfaces are brownish black, fresh surfaces greenish black. Scattered 1 mm grains of biotite were noted. Map unit 5c.

Petrographic Description. Fine grained, massive, equigranular, allotriomorphic with straight to serrate grain boundaries. Biotite forms tabular to ragged brown grains. Some larger grains contain dark reddish brown cores and light yellow-brown rims. Traces of disseminated magnetite occur in the biotite. There is some bending of (001) cleavage. Perovskite forms euhedral to anhedral grains that are nearly isotropic. Magnetite forms disseminated, euhedral to anhedral grains. Some grains are crudely skeletal and enclose carbonate and biotite.

**Reference No. 1257**
**Sample No. F-344**

*Sovite.*

Field Description. Fine to medium grained. Weathered surfaces are rusty to pink, fresh surfaces grey. Map unit 5a.

Petrographic Description. Medium grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Carbonate forms an interlocking mosaic of anhedral grains.

**Reference No. 1258**
**Sample No. FS1 112.2' (drill core)**

*Biotite, garnet, carbonate ijolite.*

Fine grained, massive, equigranular, hypidiomorphic. Biotite forms dark reddish brown, tabular grains. Clinopyroxene forms anhedral to subhedral grains which are green aegirine-augite, interlocking with nepheline and garnet. Garnet forms euhedral, deep reddish brown grains. Some possibly zoned grains have turbid cores with traces of carbonate, and are crudely skeletal. Apatite forms small anhedral grains poikilitic in garnet, pyroxene, biotite and nepheline. Fine-grained, fibrous masses are thought to be a replacment of nepheline. Sphene forms small wedge-shaped crystals. Carbonate is anhedral, interstitial.

**Reference No. 1259**
**Sample No. FS1 139.6' (drill core)**

*Magnetite, apatite, amphibole, biotite sovite.*

Fine grained, massive, equigranular, hypidiomorphic. Magnetite is anhedral, disseminated, and occurs in close association with biotite. One grain of magnetite encloses biotite. Amphibole

forms acicular, subhedral crystals with ragged terminations. Apatite is anhedral and forms rounded to rounded-elongate grains. Carbonate forms an interlocking, anhedral mosaic. Biotite occurs as tabular, anhedral, deep reddish brown grains.

**Reference No. 1260**
**Sample No. FS1 147.0' (drill core)**

*Garnet, phlogopite-biotite silicocarbonatite.*

Fine to medium grained, massive, inequigranular-seriate, allotriomorphic with straight to curved grain boundaries. Phlogopite-biotite forms tabular, irregular grains which locally enclose garnet, and are pleochroic in light brown to greenish-brown. Grains may have cuspate margins with carbonate. Some grains contain poikilitic carbonate, garnet, apatite and magnetite. Some appear poikiloblastic. Phlogopite-biotite may display traces of deep reddish brown rimming on the grains. Minor anhedral magnetite is disseminated.

**Reference No. 1261**
**Sample No. FS1 150.8' (drill core)**

*Clinopyroxene, apatite, garnet, biotite silicocarbonatite.*

Fine to medium grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Clinopyroxene is colourless, subrounded, subhedral to anhedral in outline. Pyroxene is a very minor component. Garnet forms anhedral irregular grains with abundant enclosed carbonate. Several grains have carbonate in core. Some apatite is intergrown with garnet. Some garnet may be poikiloblastic. Apatite forms rounded to rounded-elongate, anhedral grains often as intergranular aggregates between biotite and garnet. Biotite forms tabular grains; pleochroic in brown; some grains contain poikilitic carbonate, magnetite and apatite. Biotite grain boundaries with carbonate are cuspate. Some grains have traces of reddish brown rims. Some of the larger grains are slightly poikiloblastic. Carbonate is anhedral and interstitial.

**Reference No. 1262**
**Sample No. FS1 166.1' (drill core)**

*Amphibole sovite.*

Fine to medium grained, massive, equigranular, allotriomorphic. Amphibole occurs as acicular, colourless grains with ragged ends. Traces of anhedral apatite and biotite are present.

**Reference No. 1263**
**Sample No. FS1 176.7' (drill core)**

*Carbonate, biotite ijolite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Sphene is a minor accessory occurring as anhedral to subhedral grains. Biotite forms brown to reddish brown, tabular grains; it encloses clinopyroxene and magnetite. Clinopyroxene is anhedral, turbid, and green in colour. Pyroxene is an aegirine augite, and occurs as aggregates of grains and interlocking with biotite. Locally it encloses sphene. Magnetite is anhedral and disseminated. Possible nepheline occurs as anhedral, interstitial grains that are turbid and completely altered to very fine-grained fibrous masses. Carbonate is anhedral and interstitial.

**Reference No. 1264**
**Sample No. FS1 273.9' (drill core)**

*Garnet, magnetite, carbonate, biotite ijolite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Biotite forms anhedral, tabular grains interlocking with clinopyroxene. Pleochroism is brown to reddish brown. Clinopyroxene is an anhedral pale green to green aegirine augite closely associated with biotite. Possible nepheline occurs as anhedral, very fine grained turbid, masses, interstitial to pyroxene. Some of the alteration is fibrous and may be zeolite. Garnet is anhedral and forms deep reddish brown grains in association with pyroxene and magnetite. Magnetite is anhedral, disseminated and closely associated with garnet. Carbonate is anhedral and interstitial.

**Reference No. 1265**
**Sample No. FS1 279.0' (drill core)**

*Carbonate, biotite ijolite.*

Fine grained, equigranular, massive, allotriomorphic with curved to straight grain boundaries. Biotite forms anhedral to subhedral, tabular grains, reddish brown in colour. Clinopyroxene is anhedral, somewhat rounded, turbid, and green in colour. Pyroxene is an aegirine augite.

Nepheline(?) occurs as turbid, very fine grained, completely altered grains interstitial to clinopyroxene and biotite. Carbonate is anhedral and interstitial. Trace to minor amounts of accessory sphene, apatite and magnetite are present.

**Reference No. 1266**
**Sample No. FS1 290.2' (drill core)**

*Magnetite, pyroxene, biotite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Sphene occurs as anhedral to subhedral, crudely wedge-shaped grains. Biotite occurs as tabular, brown to dark brown, anhedral grains which locally contain magnetite inclusions. Clinopyroxene is anhedral, turbid, green in colour, possibly aegirine augite. Edges are ragged and fibrous and pyroxene appears to be altering to amphibole. Magnetite is anhedral and disseminated. Carbonate is an anhedral interlocking mosaic.

**Reference No. 1267**
**Sample No. FS2 42.1-42.25' (drill core)**

*Magnetite, biotite-phlogopite, clinopyroxene silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Magnetite forms anhedral, disseminated grains, poikilitic in biotite and clinopyroxene. Biotite-phlogopite forms tabular grains commonly with pale yellow cores and reddish brown rims. It contains the occasional magnetite grain. Clinopyroxene is anhedral to subhedral, colourless, generally elongate in form and occasionally contains a grain of magnetite. Carbonate is anhedral and forms an interlocking mosaic of grains.

**Reference No. 1268**
**Sample No. FS2 157.8-158.2' (drill core)**

*Biotite, garnet, carbonate ijolite.*

Fine grained, massive, equigranular, hypidiomorphic. Biotite forms tabular, reddish brown grains interlocking with pyroxene and garnet. Garnet forms reddish brown, anhedral to euhedral crystals. In some grains, cores are darker than rims, suggesting zoning. Garnet is disseminated throughout. There are a few clear, irregular grains of potassium feldspar. Apatite forms rounded to rounded-elongate grains, poikilitic in nepheline. Nepheline is totally altered to fibrous masses of zeolites(?). Clinopyroxene is anhedral, green in colour (sodic), interlocking with biotite and former nepheline. Carbonate is anhedral and interstitial to the other minerals.

**Reference No. 1269**
**Sample No. FS2 191.2-191.7' (drill core)**

*Apatite, biotite, pyroxene sovite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms rounded to rounded-elongate grains which are scattered throughout. Magnetite is anhedral, disseminated, and very minor. Biotite forms reddish brown, tabular grains at least locally interlocking with pyroxene. Clinopyroxene forms green to pale green, stubby to almost rounded crystals. Carbonate forms an interlocking mosaic of anhedral crystals.

**Reference No. 1270**
**Sample No. H2 213.8-214.2' (drill core)**

*Amphibole, magnetite, biotite, pyroxene silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Amphibole forms greenish, interlocking, stubby grains. The mineral occurs in clots and contains many isolated grains of magnetite. Amphibole is interlocking with magnetite. Magnetite is anhedral, disseminated throughout, and poikilitic in pyroxene and biotite. Biotite forms tabular, brown to pale brown grains, commonly interlocking and closely associated with magnetite. Biotite may enclose magnetite grains, sometimes as a collection of small grains in core of biotite grain. Clinopyroxene forms rounded, anhedral grains and commonly contains very fine grained magnetite inclusions. Carbonate forms an interlocking, anhedral, interstitial mosaic.

**Reference No. 1271**
**Sample No. H2 227.7-228.4' (drill core)**

*Magnetite, perovskite, amphibole, zeolite, pyroxene, biotite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Perovskite forms very tiny, euhedral crystals. Magnetite is anhedral and disseminated through-

out. Biotite is ragged, pale yellow-brown to brown in colour and may enclose pyroxene and magnetite. Rims of some grains are nearly colourless. One large former olivine(?) grain is altered to chlorite. Traces of euhedral opaque mineral occur along edges of carbonate blebs, and are possibly iron oxide after pyrite. Zeolite occurs as fibrous aggregates and as occasional isotropic fillings within centres of carbonate blebs. The zeolites are possibly natrolite(?) and analcite (isotropic phase). Amphibole occurs as very fine grained, acicular grains. Clinopyroxene is very fine grained, interlocking, very pale green, and tends to be elongated and oriented subparallel. Carbonate forms anhedral, interstitial grains and large coarse-grained elliptical clots with zeolite-bearing cores. Euhedral crystal faces of carbonate project into zeolitic cores. The zeolite in most cases is analcite(?) but some natrolite(?) may be present in one carbonate clot. The clots may be a result of liquid immiscibility.

**Reference No. 1272**
**Sample No. H2 233.7-234.2' (drill core)**

*Magnetite, amphibole, biotite silicocarbonatite.*

Fine to medium grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Sphene occurs as euhedral, brown crystals in trace amounts. Traces of prismatic zeolite(?) occur within or associated with elliptical carbonate blebs. Analcite(?) is turbid, irregular and isotropic, enclosing carbonate and occurring within some elliptical carbonate clots. Carbonate is found as anhedral, interstitial grains and as large (up to 1 cm) very coarse grained, elliptical clots. Carbonate may be the result of immiscibility. Amphibole forms colourless, acicular needles which are randomly oriented in a jackstraw pattern. Biotite forms tabular, brown grains and may enclose magnetite and amphibole. Margins of some grains have a narrow colourless rim. Rims are ragged, almost lobate, and appear to be phlogopite or biotite. Some biotite and amphibole are crudely tangential to outline of carbonate blebs.

**Reference No. 1273**
**Sample No. H2 282.1-282.7' (drill core)**

*Olivine, magnetite, phlogopite, amphibole silicocarbonatite.*

Fine grained, massive, equigranular, hypidiomorphic to allotriomorphic with straight to curved grain boundaries. Olivine occurs as rounded grains, totally altered to serpentine and chlorite. Phlogopite forms tabular, interlocking grains with ragged edges. Some grains have very narrow, completely colourless rims. Magnetite is anhedral, disseminated and may be poikilitic in biotite. Carbonate is anhedral and interstitial to other minerals.

**Reference No. 1274**
**Sample No. H2 290.5-291.15' (drill core)**

*Magnetite-bearing, biotite, apatite pyroxene sovite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms anhedral, rounded grains. Clinopyroxene is anhedral to subhedral in form, green in colour, acicular or elongate in form. The pyroxene is a sodic variety, possibly aegirine-augite. Biotite forms rounded, somewhat tabular, reddish brown grains. Biotite locally encloses carbonate blebs and small magnetite grains.

**Reference No. 1275**
**Sample No. H3 103.4-103.85' (drill core)**

*Magnetite, phlogopite, olivine silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic, with curved to straight grain boundaries. Olivine is subhedral in form and contains serpentine along curved fractures and grain boundaries. Magnetite is anhedral to subhedral, and disseminated throughout. Magnetite is enclosed in phlogopite. Phlogopite forms tabular grains, some with poorly developed, reddish brown rims. Carbonate forms anhedral interlocking grains, interstitial to olivine and phlogopite.

**Reference No. 1276 (not analysed)**
**Sample No. H3 245.4-245.8' (drill core)**

*Olivine-bearing, apatite, magnetite, phlogopite-biotite sovite.*

Fine grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Magnetite is anhedral and disseminated. Carbonate forms an interlocking mosaic. Olivine forms irregular, anhedral grains altering to chlorite and serpentine. Traces of acicular amphibole are present. Phlogopite-biotite forms irregular, tabular grains with pale yellow cores (phlogopite) and reddish brown rims (biotite). Apatite forms rounded to rounded-elongate crystals disseminated throughout.

**Reference No. 1277**
**Sample No. H3 47.1-47.5' (drill core)**

*Magnetite, garnet, pyroxene, biotite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Apatite is anhedral, and occurs as rounded grains, scattered throughout. Garnet occurs as rounded aggregates of grains and individual subhedral crystals. Garnet is dark reddish brown and may enclose carbonate, pyroxene and biotite in a sieve-like texture. Biotite forms tabular, brown, interlocking grains, slightly darkened along rims; it may contain poikilitic garnet. Clinopyroxene forms anhedral grains, pale green in colour, interlocking with biotite and garnet. Magnetite forms anhedral, irregular grains, which enclose irregular blebs of carbonate and biotite and interlock with garnet. Carbonate forms an anhedral, interlocking mosaic. Traces of sphene are present.

**Reference No. 1278**
**Sample No. H4 18.9-19.4' (drill core)**

*Magnetite-bearing, biotite, pyroxene apatite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms an interlocking aggregate of subangular grains. Clinopyroxene forms anhedral to crudely subhedral, somewhat elongate grains, green to pale green in colour. Small grains of biotite occur along margins of some pyroxene grains. Scattered small grains of magnetite occur within pyroxene. Biotite forms an interlocking mass of tabular, reddish brown grains. Some grains interlock with pyroxene and magnetite. Magnetite is anhedral, disseminated, and interlocks with pyroxene and biotite. Sphene forms tiny brown, wedge-shaped crystals. Carbonate forms interstitial anhedral grains.

**Reference No. 1279**
**Sample No. H4 162.7-163.2' (drill core)**

*Apatite-bearing, clinopyroxene, magnetite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Magnetite forms rounded, subhedral grains; an occasional bleb of carbonate is present. Apatite forms rounded to subangular grains; generally an aggregate of several grains. Clinopyroxene is anhedral, ragged, turbid, green to pale green in colour, with scattered small magnetite inclusions. Edges of some grains are clear and colourless to pale green and may be altering to amphibole. Pyroxene is a sodic variety. Carbonate is an anhedral, interlocking mosaic.

**Reference No. 1280**
**Sample No. H5 21.95-22.45' (drill core)**

*Garnet-bearing, carbonate, biotite malignite.*

Fine grained, massive, inequigranular-seriate, allotriomorphic with curved to straight grain boundaries. Sphene forms small crudely wedge-shaped crystals with high relief. Biotite forms irregular, greenish brown grains and may poikilitically enclose pyroxene. Orthoclase forms large, irregular, clear grains enclosing crudely blocky, altered nepheline. The orthoclase tends to be oikocrystic and in places partially encloses clinopyroxene. Garnet is deep reddish brown and rims or encloses some clinopyroxene. Nepheline forms irregular to blocky masses, totally altered to cancrinite and zeolites. Clinopyroxene is a green, anhedral, interlocking sodic variety (aegirine-augite) and locally has isolated patches of biotite on flanks of some grains.

**Reference No. 1281**
**Sample No. H5 65.1-65.65' (drill core)**

*Apatite, biotite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Biotite forms tabular, greenish brown to reddish brown grains. The biotite forms an interlocking mosaic crudely subparallel and defining a foliation. Zircon forms tiny poikilitic grains in biotite with radioactive bombardment haloes. Sphene occurs as wedge-shaped crystals and as composites of several irregular grains. Carbonate forms an interlocking mosaic of interlocking, anhedral grains.

**Reference No. 1282**
**Sample No. H5 69.3-69.75' (drill core)**

*Pyroxene, biotite silicocarbonatite.*

Fine grained, equigranular, massive, allotriomorphic with curved to straight grain boundaries. Scattered, very fine-grained alteration consists of iron oxide and chlorite-biotite.

Clinopyroxene(?) is greenish brown, ragged and very fine grained. Clinopyroxene(?) occurs as aggregates of grains and is intimately mixed with biotite. Some ragged relicts of colourless clinopyroxene are present. Biotite forms reddish brown, anhedral grains, interlocking with clinopyroxene.

**Reference No. 1283**
**Sample No. H5 105.9–106.5' (drill core)**

*Clinopyroxene, biotite silicocarbonatite.*

Fine to medium grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Biotite forms tabular, anhedral, brown, interlocking crystals, with mottled extinction and traces of poikilitic, very fine-grained magnetite. Magnetite is anhedral, disseminated. Clinopyroxene is altered to a very fine-grained, turbid mineral interlocking with biotite. Carbonate is anhedral and interlocking with other minerals.

**Reference No. 1284**
**Sample No. H5 153.0–153.6' (drill core)**

*Carbonate, biotite, garnet ijolite.*

Fine to medium grained, massive, equigranular, allotriomorphic with curved grain boundaries. Nepheline forms anhedral, rounded to blocky grains, totally altered to cancrinite and fibrous zeolites. Clinopyroxene is colourless, anhedral to subhedral and closely associated with former nepheline. Biotite forms brown to reddish brown grains associated with garnet, nepheline, pyroxene and magnetite. Garnet forms rounded, sieve-like, anhedral grains enclosing pyroxene. Carbonate is anhedral and interstitial to other minerals.

**Reference No. 1286**
**Sample No. H7 399.5–400.0' (drill core)**

*Magnetite, olivine, pyroxene, phlogopite-biotite sovite.*

Fine to medium grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Olivine occurs as a skeletal eutectic-like intergrowth with carbonate. Apatite occurs as anhedral to euhedral crystals. Phlogopite-biotite forms anhedral, irregular to roughly tabular grains with ragged edges; pleochroism is a very pale yellow to dark brown. It locally contains blebs of carbonate and also displays irregular intergrowths of carbonate which imply simultaneous crystallization. Very fine-grained opaques occur along cleavage planes in biotite-phlogopite. Magnetite is anhedral, irregular, disseminated and associated with pyroxene and biotite-phlogopite. Clinopyroxene is colourless, irregular, contains blebs of carbonate, and locally has grains of magnetite along edges.

**Reference No. 1287**
**Sample No. H8 19.35–19.8' (drill core)**

*Apatite-bearing, pyroxene, biotite sovite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Biotite forms tabular, reddish brown grains. Clinopyroxene forms acicular, dark green, ragged grains of aegirine-augite, which occur in aggregates as well as isolated crystals. Apatite forms rounded, anhedral grains. Carbonate is anhedral and forms an interlocking mosaic.

**Reference No. 1288**
**Sample No. H8 62.75–63.2' (drill core)**

*Apatite, pyroxene, biotite silicocarbonatite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms rounded to rounded-elongate grains, poikilitic in biotite. Biotite forms brown, often mottled, tabular grains with darker brown cores than rims. Clinopyroxene is euhedral, interlocking with biotite, colourless and often turbid along grain margins. Alteration forms rounded patches of dark brown colour containing iron oxide and carbonate. Some tabular biotite grains are tangential to clots and other biotite grains with random orientation are contained within. Magnetite is fine grained, massive, anhedral and disseminated. Carbonate is anhedral and forms an interlocking mosaic.

**Reference No. 1289**
**Sample No. H8 135.65–136.05' (drill core)**

*Apatite, clinopyroxene sovite.*

Fine grained, massive, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms rounded, bead-like to elongate grains. Clinopyroxene is anhedral to subhedral,

green in colour, and often totally altered to a turbid, very fine-grained, crudely prismatic mineral, possibly a very pale green amphibole. Apatite is poikilitic in pyroxene. Carbonate forms an anhedral interlocking mosaic.

**Reference No. 1290**
**Sample No. H8 149.1-149.75' (drill core)**

*Carbonate, biotite ijolite.*

Fine to medium grained, massive, equigranular, allotriomorphic with straight to curved grain boundaries. Albite forms anhedral, irregular grains flecked with traces of saussurite. Aegirine-augite forms ragged, green, acicular grains. Biotite is anhedral to subhedral, tabular, reddish brown and interlocking; some grains display faint zoning with brown cores and reddish brown rims. Totally altered nepheline forms fine-grained, felty masses, possibly of zeolite. Apatite is rounded to rounded-elongate. Carbonate grains are euhedral and form an interlocking mosaic.

**Reference No. 1291**
**Sample No. H8 227.6-228.1' (drill core)**

*Carbonate, garnet, biotite ijolite.*

Fine to medium grained, massive, inequigranular-seriate, allotriomorphic with straight to curved grain boundaries. Carbonate is anhedral, forming an interlocking mosaic of grains. Traces of zircon have radioactive bombardment haloes. Clinopyroxene is anhedral to subhedral, colourless, and locally poikilitically encloses apatite and interlocks with nepheline, carbonate and magnetite. Apatite forms rounded, somewhat bead-like grains. Nepheline forms anhedral grains interlocking with pyroxene and each other. The mineral is turbid along edges, but commonly fresh in the centre, with apatite poikilitically enclosed. Magnetite is anhedral and disseminated. Biotite forms euhedral, irregular, greenish-brown grains. Larger grains contain poikilitic carbonate, apatite and magnetite. Garnet forms euhedral, irregular clots that contain abundant inclusions to the point that the sieve texture is incomplete. Clinopyroxene, nepheline and carbonate are enclosed. Garnet is deep reddish brown. Some garnet is enclosed in biotite.

**Reference No. 1291B**
**Sample No. H8 285.4-285.8' (drill core)**

*Apatite, pyroxene, biotite silicocarbonatite.*

Fine grained equigranular, massive, hypidiomorphic. Apatite forms rounded to rounded-elongate grains. Clinopyroxene is a colourless, euhedral to anhedral pyroxene. Fine-grained magnetite is poikilitic in several grains. Biotite forms anhedral somewhat tabular grains which have red-brown cores and dark brown, turbid rims and poikilitically enclose apatite. Apatite forms rounded to somewhat rounded-elongated grains. Magnetite is euhedral and disseminated. Carbonate forms an anhedral, interlocking mosaic.

**Reference No. 1292**
**Sample No. H8 298.0-298.55' (drill core)**

*Apatite, phlogopite, olivine silicocarbonatite.*

Fine to medium grained, equigranular, allotriomorphic with curved to straight grain boundaries. Apatite forms rounded, bead-like grains. Carbonate grains form an anhedral, interlocking mosaic. Phlogopite forms tabular, yellow-brown booklets commonly oriented subparallel; bending of (001) cleavage is common. It contains poikilitic magnetite and apatite; some grains have darker brown cores than rims. Minor chlorite occurs as turbid, irregular grains. Alteration mineral(s) (biotite, iron oxide, chlorite and iddingsite) are very fine grained. Much of the alteration may have been after olivine as several grains contain traces of relict olivine(?). Some grains may be after pyroxene. Apatite was poikilitic in the original mineral.

**TABLE A-2. MAJOR ELEMENT ANALYSES (WEIGHT PERCENT) OF WHOLE-ROCK SAMPLES FROM THE FIRESAND RIVER CARBONATITE COMPLEX.**

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1262 | 1244 | 1246 | 1247 | 1248 | 1249 | 1250 |
| $SiO_2$ | 2.57 | 6.93 | 5.65 | 12.95 | 1.67 | 25.14 | 11.75 |
| $Al_2O_3$ | 2.46 | 0.52 | 0.93 | 1.19 | 0.41 | 0.60 | 0.57 |
| $Fe_2O_3$ | 0.00 | 2.06 | 0.00 | 1.13 | 0.00 | 0.0 | 0.41 |
| FeO | 0.97 | 2.25 | 3.78 | 3.94 | 0.97 | 0.56 | 0.64 |
| MgO | 0.73 | 4.58 | 2.19 | 3.24 | 0.36 | 0.21 | 0.38 |
| CaO | 52.6 | 44.8 | 44.4 | 39.4 | 52.4 | 39.0 | 45.6 |
| $Na_2O$ | 0.58 | 1.22 | 0.43 | 1.37 | 0.71 | 0.17 | 0.59 |
| $K_2O$ | 0.11 | 0.27 | 0.53 | 1.45 | 0.05 | 0.0 | 0.0 |
| $TiO_2$ | 0.00 | 0.20 | 0.22 | 0.25 | 0.0 | 0.0 | 0.03 |
| $P_2O_5$ | 1.17 | 1.14 | 6.04 | 2.70 | 0.44 | 1.08 | 1.04 |
| S | 0.16 | 0.03 | 0.02 | 0.02 | <0.01 | <0.01 | 0.01 |
| MnO | 0.10 | 0.31 | 0.27 | 0.35 | 0.20 | 0.29 | 0.26 |
| $CO_2$ | 38.2 | 34.5 | 34.0 | 30.6 | 42.5 | 31.4 | 37.1 |
| $H_2O+$ | 0.02 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O-$ | 0.55 | 0.37 | 0.31 | 0.39 | 0.37 | 0.41 | 0.43 |
| Total | 100.20 | 99.20 | 98.80 | 99.00 | 100.10 | 98.90 | 98.80 |

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1251 | 1252 | 1253 | 1255 | 1256 | 1257 | 1228 |
| $SiO_2$ | 8.93 | 30.22 | 2.49 | 2.76 | 16.36 | 3.31 | 34.20 |
| $Al_2O_3$ | 1.78 | 2.14 | 0.35 | 0.41 | 2.73 | 0.60 | 4.56 |
| $Fe_2O_3$ | 0.54 | 6.05 | 0.0 | 0.06 | 3.28 | 0.0 | 2.20 |
| FeO | 4.27 | 6.12 | 0.40 | 3.78 | 4.75 | 0.89 | 7.13 |
| MgO | 2.66 | 5.55 | 0.37 | 18.04 | 13.88 | 1.28 | 10.1 |
| CaO | 41.0 | 27.80 | 52.6 | 28.4 | 22.4 | 49.2 | 11.7 |
| $Na_2O$ | 0.81 | 1.95 | 1.01 | 0.30 | 1.42 | 0.62 | 0.11 |
| $K_2O$ | 1.98 | 1.11 | 0.07 | 0.01 | 1.51 | 0.27 | 3.47 |
| $TiO_2$ | 0.67 | 0.26 | 0.0 | 0.0 | 1.78 | 0.00 | 1.27 |
| $P_2O_5$ | 1.76 | 0.02 | 0.0 | 0.06 | 0.90 | 5.68 | 0.97 |
| S | 0.06 | 0.79 | <0.01 | 0.20 | 0.12 | 0.01 | 0.49 |
| MnO | 0.70 | 0.51 | 0.16 | 0.66 | 0.25 | 0.18 | 0.41 |
| $CO_2$ | 32.9 | 16.1 | 41.5 | 43.6 | 27.1 | 38.20 | 22.65 |
| $H_2O+$ | 0.0 | 0.0 | 0.0 | 0.01 | 0.23 | 0.00 | 0.26 |
| $H_2O-$ | 0.47 | 0.38 | 0.43 | 0.45 | 1.43 | 0.48 | 0.46 |
| Total | 98.50 | 99.00 | 00.40 | 98.70 | 98.10 | 100.70 | 100.00 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1262 | FS1 166.1 | 1251 | F 185B |
| 1244 | F 59 | 1252 | F 195 |
| 1246 | F 72 | 1253 | F 208 |
| 1247 | F 112 | 1255 | F 316 |
| 1248 | F 148 | 1256 | F 341 |
| 1249 | F 176 | 1257 | F 344 |
| 1250 | F 179 | 1228 | ST-2A |

**TABLE A-2. CONTINUED.**

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1229** | **1233** | **1238** | **1225** | **1226** | **1269** | **1274** |
| $SiO_2$ | 20.87 | 25.40 | 22.70 | 22.60 | 0.30 | 20.4 | 9.45 |
| $Al_2O_3$ | 0.70 | 0.80 | 1.30 | 0.70 | 0.36 | 3.26 | 1.07 |
| $Fe_2O_3$ | 0.19 | 2.25 | 1.10 | 5.14 | 0.00 | 3.01 | 0.02 |
| FeO | 0.73 | 2.84 | 1.89 | 3.93 | 0.40 | 5.57 | 2.08 |
| MgO | 2.20 | 3.00 | 1.20 | 2.90 | 0.02 | 3.97 | 2.68 |
| CaO | 51.8 | 47.7 | 50.7 | 47.1 | 54.0 | 31.1 | 43.5 |
| $Na_2O$ | 0.03 | 0.32 | 0.05 | 0.08 | 0.07 | 1.94 | 0.81 |
| $K_2O$ | 0.10 | 0.17 | 0.51 | 0.12 | 0.04 | 1.95 | 0.59 |
| $TiO_2$ | 0.10 | 0.01 | 0.10 | 0.10 | 0.00 | 0.96 | 0.19 |
| $P_2O_5$ | 0.60 | 2.16 | 2.12 | 1.50 | 0.03 | 4.14 | 3.71 |
| S | 0.13 | 0.31 | 0.02 | 0.17 | 0.01 | 0.20 | 0.16 |
| MnO | 0.16 | 0.36 | 0.92 | 0.33 | 0.14 | 0.26 | 0.12 |
| $CO_2$ | 41.9 | 34.5 | 36.7 | 33.4 | 43.0 | 20.6 | 33.8 |
| $H_2O+$ | 0.04 | 0.07 | 0.19 | 0.35 | 0.18 | 0.46 | 0.19 |
| $H_2O-$ | 0.19 | 0.21 | 0.36 | 0.13 | 0.04 | 0.23 | 0.19 |
| Total | 99.60 | 100.10 | 99.80 | 98.40 | 98.60 | 98.10 | 98.60 |

| | Sovite (Unit 5a,b,7a) | | | | Silicocarbonatite (Unit 5c,7b) | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1286** | **1287** | **1289** | **1259** | **1267** | **1270** | **1271** |
| $SiO_2$ | 14.3 | 40.6 | 5.22 | 6.54 | 25.9 | 24.1 | 32.8 |
| $Al_2O_3$ | 1.68 | 11.7 | 1.46 | 2.73 | 3.74 | 4.74 | 8.39 |
| $Fe_2O_3$ | 2.46 | 2.95 | 0.07 | 1.37 | 4.11 | 5.02 | 6.33 |
| FeO | 4.41 | 8.15 | 1.83 | 3.22 | 7.82 | 5.74 | 6.99 |
| MgO | 5.30 | 7.06 | 0.60 | 2.52 | 11.6 | 9.36 | 7.70 |
| CaO | 40.5 | 10.4 | 47.8 | 46.50 | 20.9 | 23.8 | 17.4 |
| $Na_2O$ | 0.34 | 3.42 | 0.76 | 0.71 | 0.93 | 0.54 | 2.39 |
| $K_2O$ | 0.89 | 5.74 | 0.27 | 0.76 | 3.44 | 3.64 | 2.30 |
| $TiO_2$ | 0.60 | 0.95 | 0.04 | 0.48 | 3.54 | 2.59 | 4.43 |
| $P_2O_5$ | 6.55 | 0.28 | 2.14 | 3.80 | 0.03 | 2.93 | 1.33 |
| S | 0.16 | 0.34 | 0.51 | 0.22 | 0.39 | 0.35 | 0.35 |
| MnO | 0.26 | 0.36 | 0.12 | 0.32 | 0.37 | 0.34 | 0.25 |
| $CO_2$ | 2.19 | 4.79 | 3.75 | 29.20 | 13.3 | 13.0 | 5.03 |
| $H_2O+$ | 0.24 | 1.14 | 0.14 | 0.01 | 0.28 | 0.54 | 2.07 |
| $H_2O-$ | 0.26 | 0.37 | 0.21 | 0.89 | 0.18 | 0.30 | 0.40 |
| Total | 99.90 | 98.30 | 98.70 | 99.30 | 96.50 | 97.00 | 98.20 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1229 | ST-5 | 1286 | H7 399.5-400.0 |
| 1233 | ST-20 | 1287 | H8 19.35-19.8 |
| 1238 | ST-70 | 1289 | H8 135.65-136.05 |
| 1225 | FS 4B2 | 1259 | FS 1 139.6 |
| 1226 | FS 7 | 1267 | FS 2 42.1-42.25 |
| 1269 | H2 191.2-191.7 | 1270 | H2 213.8-214.2 |
| 1274 | H2 290.5-291.15 | 1271 | H2 227.7-228.4 |

TABLE A-2. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1272 | 1273 | 1275 | 1277 | 1278 | 1279 | 1281 |
| $SiO_2$ | 30.6 | 30.8 | 23.0 | 20.3 | 25.1 | 4.71 | 25.6 |
| $Al_2O_3$ | 8.26 | 5.69 | 3.21 | 3.96 | 2.96 | 0.58 | 6.61 |
| $Fe_2O_3$ | 5.66 | 6.57 | 8.19 | 2.95 | 3.80 | 0.60 | 1.89 |
| FeO | 7.24 | 8.49 | 8.65 | 6.32 | 11.6 | 23.8 | 8.74 |
| MgO | 9.10 | 14.3 | 17.7 | 5.85 | 7.73 | 2.15 | 7.42 |
| CaO | 16.3 | 12.9 | 16.1 | 30.2 | 24.40 | 19.1 | 21.1 |
| $Na_2O$ | 2.66 | 2.44 | 0.35 | 0.63 | 0.93 | 0.73 | 0.61 |
| $K_2O$ | 2.19 | 2.78 | 1.88 | 2.56 | 2.55 | 0.12 | 5.67 |
| $TiO_2$ | 4.44 | 4.47 | 2.92 | 1.31 | 1.58 | 3.51 | 1.08 |
| $P_2O_5$ | 1.20 | 0.86 | 1.48 | 4.21 | 5.84 | 2.87 | 1.93 |
| S | 0.19 | 0.23 | 0.17 | 0.28 | 1.89 | 0.83 | 0.02 |
| MnO | 0.23 | 0.24 | 0.43 | 0.56 | 0.53 | 0.87 | 0.58 |
| $CO_2$ | 7.25 | 6.81 | 10.3 | 17.0 | 10.1 | 10.8 | 16.0 |
| $H_2O+$ | 1.89 | 1.18 | 2.66 | 0.37 | 0.71 | 0.13 | 1.00 |
| $H_2O-$ | 0.45 | 0.55 | 0.29 | 0.20 | 0.26 | 0.18 | 0.40 |
| Total | 97.80 | 98.30 | 97.30 | 96.70 | 100.00 | 101.00 | 98.70 |

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1282 | 1283 | 1288 | 1292 | 1291B | 1261 | 1260 |
| $SiO_2$ | 25.5 | 30.0 | 23.9 | 14.8 | 15.6 | 25.40 | 22.6 |
| $Al_2O_3$ | 7.07 | 5.67 | 4.62 | 2.76 | 2.56 | 2.73 | 5.70 |
| $Fe_2O_3$ | 4.01 | 6.01 | 3.68 | 2.64 | 1.81 | 1.37 | 7.70 |
| FeO | 7.82 | 7.82 | 4.74 | 3.49 | 4.74 | 3.22 | 3.54 |
| MgO | 3.13 | 12.3 | 7.26 | 5.90 | 5.30 | 2.52 | 5.72 |
| CaO | 24.1 | 16.6 | 25.9 | 36.0 | 37.0 | 46.5 | 28.8 |
| $Na_2O$ | 0.37 | 0.47 | 1.18 | 0.78 | 0.32 | 0.71 | 0.40 |
| $K_2O$ | 4.94 | 4.64 | 3.06 | 1.70 | 1.63 | 0.76 | 2.54 |
| $TiO_2$ | 1.27 | 3.76 | 1.96 | 0.53 | 0.56 | 1.29 | 1.75 |
| $P_2O_5$ | 1.08 | 1.65 | 2.74 | 5.86 | 6.35 | 3.53 | 5.59 |
| S | 0.03 | 0.14 | 0.63 | 0.50 | 0.57 | 0.53 | 0.55 |
| MnO | 0.52 | 0.70 | 0.29 | 0.45 | 0.32 | 0.45 | 0.34 |
| $CO_2$ | 14.90 | 7.91 | 16.8 | 22.4 | 22.2 | 9.10 | 10.5 |
| $H_2O+$ | 0.88 | 0.21 | 1.11 | 0.93 | 0.40 | 1.87 | 0.93 |
| $H_2O-$ | 0.22 | 0.21 | 0.55 | 0.39 | 0.25 | 1.17 | 0.92 |
| Total | 96.60 | 98.10 | 98.50 | 99.10 | 99.60 | 99.30 | 97.60 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1272 | H2 233.7-234.2 | 1282 | H5 69.3-69.75 |
| 1273 | H2 282.1-282.7 | 1283 | H5 105.9-106.5 |
| 1275 | H3 103.4-103.85 | 1288 | H8 62.75-63.2 |
| 1277 | H3 47.1-47.5 | 1292 | H8 298.0-298.55 |
| 1278 | H4 18.9-19.4 | 1291B | H8 285.4-285.8 |
| 1279 | H4 162.7-163.2 | 1261 | FS 1 150.8 |
| 1281 | H5 65.1-65.65 | 1260 | FS 1 147 |

**TABLE A-2. CONTINUED.**

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1266** | **1245** | **1230** | **1231** | **1232** | **1235** | **1236** |
| $SiO_2$ | 22.6 | 29.7 | 28.6 | 28.7 | 22.1 | 29.8 | 29.5 |
| $Al_2O_3$ | 4.52 | 4.19 | 3.91 | 4.01 | 3.13 | 3.55 | 6.24 |
| $Fe_2O_3$ | 2.92 | 9.60 | 6.55 | 6.76 | 2.92 | 9.17 | 8.32 |
| FeO | 7.00 | 1.37 | 6.99 | 8.18 | 6.19 | 8.23 | 3.86 |
| MgO | 5.95 | 17.24 | 16.1 | 14.1 | 17.2 | 19.8 | 4.15 |
| CaO | 25.7 | 29.4 | 13.5 | 14.4 | 15.5 | 13.2 | 21.5 |
| $Na_2O$ | 1.21 | 0.74 | 1.38 | 1.80 | 0.57 | 1.09 | 2.16 |
| $K_2O$ | 3.70 | 0.85 | 4.00 | 3.61 | 2.28 | 1.64 | 3.76 |
| $TiO_2$ | 1.51 | 2.05 | 4.42 | 4.02 | 3.32 | 5.33 | 1.85 |
| $P_2O_5$ | 3.33 | 0.92 | 0.39 | 0.56 | 0.11 | 0.96 | 0.49 |
| S | 0.21 | 0.03 | 0.02 | 0.06 | 0.15 | 0.13 | 1.36 |
| MnO | 0.38 | 0.34 | 0.56 | 0.57 | 0.61 | 0.25 | 0.46 |
| $CO_2$ | 17.3 | 11.7 | 11.14 | 10.62 | 25.45 | 3.62 | 16.2 |
| $H_2O+$ | 0.78 | 0.42 | 0.49 | 0.76 | 0.28 | 1.03 | 0.64 |
| $H_2O-$ | 0.72 | 0.66 | 0.29 | 0.25 | 0.23 | 0.28 | 0.46 |
| Total | 97.80 | 99.10 | 98.40 | 98.40 | 100.00 | 98.10 | 101.00 |

| | Silicocarbonatite (Unit 5c,7b) | | | | | | Ijolite (Unit 5c, 7b) |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1239** | **1240** | **1241** | **1243** | **1222** | **1223** | **1258** |
| $SiO_2$ | 33.2 | 24.2 | 21.8 | 28.5 | 17.4 | 26.2 | 30.1 |
| $Al_2O_3$ | 10.9 | 3.60 | 5.30 | 6.29 | 9.24 | 3.45 | 6.49 |
| $Fe_2O_3$ | 5.63 | 11.3 | 3.63 | 3.70 | 5.36 | 10.4 | 5.24 |
| FeO | 6.55 | 5.82 | 6.55 | 9.25 | 4.63 | 6.04 | 5.55 |
| MgO | 4.46 | 13.1 | 6.60 | 14.8 | 9.14 | 13.8 | 8.42 |
| CaO | 19.2 | 18.5 | 27.8 | 9.27 | 35.8 | 18.1 | 24.90 |
| $Na_2O$ | 3.29 | 1.17 | 1.35 | 0.77 | 0.16 | 1.40 | 0.59 |
| $K_2O$ | 4.56 | 3.08 | 3.60 | 4.14 | 0.37 | 2.57 | 4.09 |
| $TiO_2$ | 2.51 | 5.13 | 0.40 | 3.52 | 0.81 | 5.43 | 1.68 |
| $P_2O_5$ | 1.90 | 1.00 | 2.22 | 0.32 | 0.69 | 0.55 | 0.37 |
| S | 0.23 | 0.16 | 0.01 | 0.04 | 0.09 | 0.23 | 0.06 |
| MnO | 0.35 | 0.35 | 0.39 | 0.41 | 0.85 | 0.34 | 0.39 |
| $CO_2$ | 4.28 | 10.6 | 18.0 | 16.75 | 15.6 | 9.52 | 9.85 |
| $H_2O+$ | 0.88 | 0.56 | 0.42 | 1.02 | 0.37 | 1.11 | 2.11 |
| $H_2O-$ | 0.28 | 0.35 | 0.32 | 0.84 | 0.10 | 0.30 | 0.16 |
| Total | 98.20 | 98.90 | 98.40 | 99.60 | 100.60 | 99.40 | 98.60 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1266 | FS 1 290.2 | 1239 | ST 76 |
| 1245 | F 59C | 1240 | ST 81 |
| 1230 | ST 10A | 1241 | ST 84 |
| 1231 | ST 10D | 1243 | ST 97 |
| 1232 | ST 11 | 1222 | FS 2A 5 |
| 1235 | ST 26 | 1223 | FS 2C1 |
| 1236 | ST 34 | 1258 | FS 1 112.2 |

TABLE A-2. CONTINUED.

| | Ijolite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1264 | 1265 | 1234 | 1237 | 1242 | 1268 | 1280 |
| $SiO_2$ | 29.1 | 31.9 | 28.7 | 31.1 | 28.6 | 32.3 | 32.9 |
| $Al_2O_3$ | 8.13 | 9.12 | 4.15 | 10.6 | 6.76 | 10.4 | 9.54 |
| $Fe_2O_3$ | 6.65 | 5.19 | 9.03 | 3.53 | 9.58 | 5.56 | 2.73 |
| FeO | 4.91 | 7.57 | 3.13 | 8.08 | 5.24 | 6.16 | 5.74 |
| MgO | 5.15 | 3.30 | 6.26 | 4.34 | 4.29 | 3.79 | 4.27 |
| CaO | 26.0 | 20.4 | 30.3 | 19.7 | 27.2 | 20.0 | 20.8 |
| $Na_2O$ | 1.30 | 2.42 | 0.74 | 3.78 | 1.82 | 1.30 | 0.80 |
| $K_2O$ | 2.79 | 2.69 | 0.83 | 3.42 | 1.92 | 3.93 | 3.77 |
| $TiO_2$ | 2.18 | 1.92 | 3.17 | 1.86 | 1.63 | 1.45 | 0.95 |
| $P_2O_5$ | 1.97 | 1.76 | 3.70 | 1.90 | 2.80 | 1.90 | 0.08 |
| S | 0.21 | 0.55 | 0.11 | 1.68 | 0.55 | 1.07 | 1.03 |
| MnO | 0.41 | 0.53 | 0.25 | 0.33 | 0.50 | 0.43 | 0.32 |
| $CO_2$ | 8.65 | 9.25 | 6.52 | 8.16 | 7.04 | 7.72 | 12.4 |
| $H_2O+$ | 1.32 | 1.48 | 1.15 | 0.35 | 1.10 | 1.59 | 1.30 |
| $H_2O-$ | 0.88 | 0.92 | 0.48 | 0.22 | 0.39 | 0.30 | 0.53 |
| Total | 99.60 | 99.00 | 98.50 | 99.10 | 99.40 | 97.90 | 97.20 |

| | Ijolite (Unit 5c,7b) | | | | Rauhaugite (Unit 6a) | | Misc. |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1284 | 1290 | 1291 | 1263 | 1254 | 1227 | 1224 |
| $SiO_2$ | 32.6 | 30.5 | 28.9 | 26.3 | 1.51 | 0.40 | 45.4 |
| $Al_2O_3$ | 10.5 | 9.56 | 6.53 | 7.87 | 0.68 | 8.08 | 13.4 |
| $Fe_2O_3$ | 4.40 | 2.86 | 6.35 | 4.70 | 9.40 | 9.33 | 2.60 |
| FeO | 7.65 | 7.24 | 5.99 | 6.84 | 3.54 | 3.44 | 10.3 |
| MgO | 6.30 | 4.55 | 5.57 | 4.81 | 12.65 | 12.5 | 5.49 |
| CaO | 17.9 | 19.5 | 26.1 | 22.7 | 30.2 | 32.0 | 13.4 |
| $Na_2O$ | 0.67 | 2.10 | 1.79 | 1.26 | 0.50 | 0.08 | 2.75 |
| $K_2O$ | 5.12 | 4.94 | 2.27 | 3.00 | 0.0 | 0.04 | 0.63 |
| $TiO_2$ | 2.14 | 1.51 | 2.12 | 1.94 | 0.06 | 0.00 | 0.74 |
| $P_2O_5$ | 2.46 | 0.66 | 3.02 | 3.97 | 6.64 | 1.05 | 0.18 |
| S | 0.52 | 0.14 | 0.53 | 0.33 | 0.02 | 0.09 | 0.46 |
| MnO | 0.35 | 0.28 | 0.34 | 0.37 | 0.44 | 0.01 | 0.24 |
| $CO_2$ | 7.61 | 12.4 | 8.54 | 10.40 | 32.3 | 31.7 | 2.92 |
| $H_2O+$ | 1.21 | 1.21 | 1.05 | 1.19 | 0.00 | 0.24 | 0.90 |
| $H_2O-$ | 0.31 | 0.39 | 0.33 | 0.82 | 0.55 | 0.04 | 0.10 |
| Total | 99.70 | 97.80 | 99.40 | 96.50 | 98.50 | 99.60 | 99.50 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1264 | FS 1 273.9 | 1284 | H5 153.0-153.6 |
| 1265 | FS 1 279.0 | 1290 | H8 149.1-149.75 |
| 1234 | ST 21 | 1291 | H8 227.6-228.1 |
| 1237 | ST 62 | 1263 | FS 1 176.7 |
| 1242 | ST 86 | 1254 | F 236C |
| 1268 | FS 2 157.8-158.2 | 1227 | FS 9 |
| 1280 | H5 21.95-22.45 | 1224 | FS 2D1 |

**TABLE A-3. TRACE ELEMENT ANALYSES (PPM) OF WHOLE-ROCK SAMPLES FROM THE FIRESAND RIVER CARBONATITE COMPLEX.**

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1262** | **1244** | **1246** | **1247** | **1248** | **1249** | **1250** |
| Ag | <1 | <1 | <1 | <1 | | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 460 | 540 | 170 | 690 | 840 | 320 | 240 |
| Be | <1 | <1 | <1 | 3 | | <1 | <1 |
| Bi | | | | | | | |
| Co | 5 | 6 | <5 | 8 | <5 | <5 | <5 |
| Cr | <5 | 7 | 26 | <5 | 5 | 6 | 15 |
| Cu | 14 | 15 | 20 | 15 | 10 | 8 | 10 |
| Ga | 2 | 2 | 1 | 3 | | 1 | 2 |
| Hg | | | | | | | |
| Li | <3 | 6 | <3 | <3 | <3 | 6 | 4 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | | <1 | <1 |
| Nb | 900 | 350 | 250 | 100 | | 45 | 50 |
| Ni | <5 | <5 | <5 | <5 | <5 | <5 | <5 |
| Pb | 31 | 25 | 25 | 15 | 15 | 30 | 20 |
| Rb | <10 | <10 | <10 | 40 | <10 | <10 | <10 |
| Sb | | | | | | | |
| Sc | <5 | <5 | 15 | <5 | | <5 | <5 |
| Sn | <3 | <3 | <3 | <3 | | <3 | <3 |
| Sr | >1% | 7000 | 2000 | 7000 | | 4500 | 2.4% |
| Ti | | | | | | | |
| V | 40 | 150 | 100 | 150 | | 35 | 60 |
| Y | 80 | 100 | 400 | 150 | | 80 | 80 |
| Zn | 18 | 85 | 110 | 55 | 25 | 40 | 60 |
| Zr | 150 | 450 | 600 | 150 | | <10 | 10 |
| La | 250 | 300 | 150 | 350 | | 300 | 250 |
| Nd | 100 | 250 | 250 | 200 | | 100 | 100 |
| Ce | 290 | <50 | 300 | 410 | 260 | 400 | 290 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1262 | FS1 166.1 | 1248 | F 148 |
| 1244 | F 59 | 1249 | F 176 |
| 1246 | F 72 | 1250 | F 179 |
| 1247 | F 112 | | |

TABLE A-3. CONTINUED.

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1251 | 1252 | 1253 | 1255 | 1256 | 1257 | 1228 |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 550 | 280 | 840 | 1100 | 1200 | 910 | 420 |
| Be | 2 | 15 | <1 | 3 | 7 | <1 | 5 |
| Bi | | | | | | | |
| Co | 15 | 50 | <5 | 6 | 70 | 5 | 25 |
| Cr | 90 | 50 | <5 | 25 | 580 | 10 | 400 |
| Cu | 40 | 180 | 10 | 6 | 40 | 70 | 85 |
| Ga | 4 | 7 | <1 | <1 | 8 | <1 | 3 |
| Hg | | | | | | | |
| Li | 25 | 6 | <3 | 6 | 6 | 8 | 15 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Nb | 450 | 45 | 700 | 200 | 35 | 150 | 6 |
| Ni | 55 | 50 | <5 | <5 | 570 | 5 | 270 |
| Pb | 15 | 20 | 25 | <10 | 20 | 30 | 25 |
| Rb | 100 | 30 | <10 | <10 | 50 | 10 | 50 |
| Sb | | | | | | | |
| Sc | <5 | 10 | <5 | 20 | 10 | 7 | 30 |
| Sn | <3 | <3 | <3 | <3 | <3 | <3 | <1 |
| Sr | 9500 | 4500 | 1.4% | 4000 | 3500 | 1.0% | 900 |
| Ti | | | | | | | |
| V | 100 | 200 | 30 | <10 | 90 | 70 | 100 |
| Y | 60 | 50 | 60 | 20 | 20 | 80 | 30 |
| Zn | 370 | 140 | 20 | 45 | 140 | 20 | 65 |
| Zr | 150 | 400 | 20 | <10 | 500 | 35 | 80 |
| La | 150 | 100 | 250 | 200 | <100 | 200 | 260 |
| Nd | <100 | <100 | 100 | 100 | <100 | 100 | 220 |
| Ce | 340 | 130 | 190 | <50 | 430 | 220 | 300 |
| Yb | | | | | | | 1 |
| Eu | | | | | | | 8 |
| Sm | | | | | | | <15 |
| Gd | | | | | | | <5 |
| Dy | | | | | | | <4 |
| Y | | | | | | | 25 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Duplicate elements indicate different methods of analysis.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1251 | F 185B | 1256 | F 341 |
| 1252 | F 195 | 1257 | F 344 |
| 1253 | F 208 | 1228 | ST-2A |
| 1255 | F 316 | | |

**TABLE A-3. CONTINUED.**

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1229** | **1233** | **1238** | **1225** | **1226** | **1269** | **1274** |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 280 | 520 | 340 | 390 | 300 | 640 | 780 |
| Be | <1 | 1 | <1 | <1 | <3 | 5 | 2 |
| Bi | | | | | | | |
| Co | <5 | <5 | <5 | 5 | <4 | 18 | 6 |
| Cr | <5 | <5 | 20 | <5 | <10 | <5 | 11 |
| Cu | 10 | 20 | 10 | 10 | 4 | 28 | 20 |
| Ga | <1 | <1 | <1 | 1 | <5 | 15 | 4 |
| Hg | | | | | | | |
| Li | <3 | 5 | 15 | 5 | <20 | 6 | 7 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <10 | <1 | <1 |
| Nb | 45 | 570 | 180 | 2540 | <100 | 380 | 130 |
| Ni | 10 | <5 | 10 | <5 | 8 | <5 | <5 |
| Pb | 10 | 25 | 20 | 10 | <10 | <10 | <10 |
| Rb | <10 | <10 | 20 | <10 | | 60 | 30 |
| Sb | | | | | | | |
| Sc | <5 | <5 | <5 | <5 | <20 | 3 | 6 |
| Sn | <1 | <1 | <1 | <1 | <10 | <3 | <3 |
| Sr | 1500 | 5000 | 6000 | 5000 | 5000 | 5000 | 1% |
| Ti | | | | | | | |
| V | 15 | 200 | 80 | 500 | 100 | 450 | 150 |
| Y | 60 | 60 | 150 | 80 | 100 | 16 | 10 |
| Zn | 10 | 60 | 90 | 105 | 8 | 150 | 40 |
| Zr | <10 | 70 | <10 | 100 | <10 | 700 | 300 |
| La | 80 | 85 | 1000 | 115 | 400 | 35 | 40 |
| Nd | 210 | 170 | 500 | 310 | | 80 | 85 |
| Ce | 70 | <45 | 920 | 210 | 2000 | <35 | <30 |
| Yb | <1 | 2 | 4 | 3 | | 2 | <1 |
| Eu | 5 | 4 | 12 | 7 | | 1 | <1 |
| Sm | <15 | <15 | <15 | 20 | | <15 | <15 |
| Gd | 5 | <5 | 17 | 6 | | <5 | 5 |
| Dy | <4 | <4 | 8 | 8 | | <4 | <4 |
| Y | 15 | 24 | 85 | 25 | | | |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Duplicate elements indicate different methods of analysis.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1229 | ST-5 | 1226 | FS 7 |
| 1233 | ST-20 | 1269 | H2 191.2-191.7 |
| 1238 | ST-70 | 1274 | H2 290.5-291.15 |
| 1225 | FS 4B2 | | |

TABLE A-3. CONTINUED.

| | Sovite (Unit 5a,b,7a) | | | | Silicocarbonatite (Unit 5c,7b) | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1286 | 1287 | 1289 | 1259 | 1267 | 1270 | 1271 |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 500 | 880 | 710 | 630 | 770 | 1900 | 3540 |
| Be | <1 | 9 | <1 | 3 | 9 | 4 | 6 |
| Bi | | | | | | | |
| Co | 16 | 34 | 5 | 14 | 62 | 40 | 48 |
| Cr | <5 | 297 | <5 | <5 | 560 | 169 | 341 |
| Cu | 30 | 200 | 19 | 38 | 118 | 146 | 143 |
| Ga | 4 | 10 | 2 | 4 | 20 | 15 | 20 |
| Hg | | | | | | | |
| Li | 6 | 12 | 8 | <3 | 5 | 4 | 16 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Nb | 75 | 200 | 110 | 250 | 295 | 355 | 145 |
| Ni | <5 | 65 | <5 | <5 | 440 | 79 | 76 |
| Pb | <10 | <10 | <10 | 25 | <10 | <10 | <10 |
| Rb | 20 | 70 | <10 | 20 | 40 | 60 | 40 |
| Sb | | | | | | | |
| Sc | 2 | 20 | 1 | 5 | 15 | 22 | 22 |
| Sn | <3 | <3 | <3 | <3 | 3 | 7 | 4 |
| Sr | 6000 | 1000 | 2.3% | 7000 | 2500 | 2000 | 2000 |
| Ti | | | | | | | |
| V | 200 | 600 | 200 | 200 | 150 | 350 | 350 |
| Y | 23 | 11 | 14 | 100 | 22 | 85 | 50 |
| Zn | 83 | 180 | 20 | 72 | 180 | 170 | 160 |
| Zr | 50 | 100 | 200 | 500 | 300 | 500 | 250 |
| La | 70 | <4 | 60 | 400 | 40 | 180 | 120 |
| Nd | 105 | 30 | 170 | 600 | <30 | 135 | 90 |
| Ce | 105 | 35 | <35 | 720 | 115 | 320 | 285 |
| Yb | 1 | 2 | <1 | 5 | 2 | 6 | 4 |
| Eu | 2 | <1 | <1 | <100 | 2 | 6 | 5 |
| Sm | <15 | <15 | <15 | | <15 | 21 | 19 |
| Gd | 6 | <5 | <5 | | <5 | 8 | <5 |
| Dy | 4 | <4 | <4 | | <4 | 10 | 6 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1286 | H7 399.5-400.0 | 1267 | FS 2 42.1-42.25 |
| 1287 | H8 19.35-19.8 | 1270 | H2 213.8-214.2 |
| 1289 | H8 135.65-136.05 | 1271 | H2 227.7-228.4 |
| 1259 | FS 1 139.6 | | |

**TABLE A-3. CONTINUED.**

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1272** | **1273** | **1275** | **1277** | **1278** | **1279** | **1281** |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 1600 | 880 | 720 | 790 | 510 | 140 | 1070 |
| Be | 5 | 6 | <1 | 5 | 15 | <1 | 6 |
| Bi | | | | | | | |
| Co | 48 | 75 | 59 | 22 | 38 | 24 | 18 |
| Cr | 530 | 540 | 900 | <5 | 148 | 12 | <5 |
| Cu | 94 | 141 | 16 | 50 | 64 | 14 | <5 |
| Ga | 15 | 15 | 10 | 15 | 15 | 25 | 25 |
| Hg | | | | | | | |
| Li | 6 | 4 | 3 | 4 | 4 | 4 | 10 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <1 | 7 | <1 |
| Nb | 110 | 95 | 690 | 385 | 925 | 520 | 1920 |
| Ni | 127 | 400 | 440 | <5 | 79 | <5 | <5 |
| Pb | <10 | <13 | <10 | <10 | 33 | <10 | 16 |
| Rb | 30 | 50 | 40 | 60 | 70 | <10 | 150 |
| Sb | | | | | | | |
| Sc | 25 | 21 | 21 | 7 | 17 | 15 | 2 |
| Sn | 4 | <3 | 7 | <3 | <3 | 10 | <3 |
| Sr | 1000 | 900 | 1500 | 4500 | 3500 | 4500 | 6000 |
| Ti | | | | | | | |
| V | 400 | 400 | 350 | 300 | 1000 | 1.5% | 450 |
| Y | 40 | 35 | 18 | 65 | 45 | 40 | 22 |
| Zn | 134 | 150 | 250 | 260 | 400 | 860 | 420 |
| Zr | 300 | 300 | 400 | 1000 | 250 | 250 | 1000 |
| La | 105 | 70 | 40 | 180 | 165 | 150 | 80 |
| Nd | 80 | 45 | 120 | 170 | 175 | 120 | 85 |
| Ce | 280 | 205 | 230 | 285 | 315 | 260 | 105 |
| Yb | 3 | 3 | 3 | 4 | 4 | 14 | 3 |
| Eu | 5 | 4 | 4 | 5 | 5 | 5 | <1 |
| Sm | 20 | <15 | 19 | 20 | 21 | 30 | <15 |
| Gd | <5 | <5 | <5 | 9 | <5 | 6 | <5 |
| Dy | 5 | 4 | 5 | 10 | 7 | 6 | <4 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1272 | H2 233.7-234.2 | 1278 | H4 18.9-19.4 |
| 1273 | H2 282.1-282.7 | 1279 | H4 162.7-163.2 |
| 1275 | H3 103.4-103.85 | 1281 | H5 65.1-65.65 |
| 1277 | H3 47.1-47.5 | | |

TABLE A-3. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1282 | 1283 | 1288 | 1292 | 1291B | 1260 | 1261 |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 1640 | 1640 | 1020 | 1270 | 940 | 1200 | 2000 |
| Be | 10 | 10 | 10 | 3 | 3 | 9 | 8 |
| Bi | | | | | | | |
| Co | 10 | 58 | 36 | 17 | 18 | 27 | 35 |
| Cr | <5 | 398 | <5 | <5 | <5 | <5 | <5 |
| Cu | 5 | 66 | 133 | 57 | 54 | 72 | 96 |
| Ga | 25 | 20 | 10 | 5 | 7 | 15 | 15 |
| Hg | | | | | | | |
| Li | 7 | 6 | 8 | 4 | 4 | 4 | 7 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Nb | 1870 | 235 | 200 | 150 | 65 | 300 | 300 |
| Ni | <5 | 260 | 15 | <5 | <5 | <5 | <5 |
| Pb | 30 | <10 | <10 | <10 | <10 | 15 | 70 |
| Rb | 100 | 120 | 50 | 50 | 50 | 80 | 110 |
| Sb | | | | | | | |
| Sc | 5 | 14 | 12 | 5 | 4 | <5 | <5 |
| Sn | <3 | 3 | <3 | <3 | <3 | <3 | <3 |
| Sr | 7000 | 2000 | 3000 | 4500 | 5000 | 4000 | 3500 |
| Ti | | | | | | | |
| V | 1000 | 300 | 250 | 150 | 350 | 350 | 150 |
| Y | 22 | 75 | 22 | 55 | 35 | 150 | 90 |
| Zn | 320 | 270 | 148 | 86 | 96 | 202 | 330 |
| Zr | 1500 | 400 | 100 | 1000 | 1000 | 300 | 200 |
| La | 90 | 250 | 135 | 165 | 85 | 400 | 500 |
| Nd | 100 | 165 | 100 | 160 | 125 | 400 | 400 |
| Ce | 150 | 475 | 210 | 240 | 115 | 1080 | 1010 |
| Yb | 3 | 5 | 2 | 3 | 2 | 6 | 3 |
| Eu | 1 | 7 | 2 | 5 | 3 | <100 | <100 |
| Sm | <15 | 30 | <15 | 21 | <15 | | |
| Gd | <5 | 7 | <5 | 11 | 8 | | |
| Dy | <4 | 8 | <5 | 9 | 6 | | |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1282 | H5 69.3-69.75 | 1291B | H8 285.4-285.8 |
| 1283 | H5 105.9-106.5 | 1260 | FS 1 147 |
| 1288 | H8 62.75-63.2 | 1261 | FS 1 150.8 |
| 1292 | H8 298.0-298.55 | | |

**TABLE A-3. CONTINUED.**

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1266** | **1245** | **1230** | **1231** | **1232** | **1235** | **1236** |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 610 | 860 | 1200 | 2000 | 420 | 720 | 180 |
| Be | 9 | 20 | 6 | 5 | 10 | 4 | 7 |
| Bi | | | | | | | |
| Co | 26 | 30 | 55 | 55 | 45 | 85 | 20 |
| Cr | <5 | <5 | 600 | 800 | 580 | 40 | <5 |
| Cu | 99 | 15 | 115 | 30 | 20 | 90 | 70 |
| Ga | 15 | 15 | 6 | 6 | 6 | 10 | 10 |
| Hg | | | | | | | |
| Li | 8 | 4 | 10 | 5 | 50 | 5 | 10 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Nb | 300 | 250 | 360 | 480 | 2 | 100 | 810 |
| Ni | 5 | <5 | 580 | 480 | 300 | 580 | 5 |
| Pb | 33 | 15 | 30 | 15 | <10 | 15 | 15 |
| Rb | 100 | 20 | 140 | 100 | 40 | 50 | 80 |
| Sb | | | | | | | |
| Sc | 9 | <5 | 15 | 10 | 70 | 15 | <5 |
| Sn | 3 | <3 | <1 | <1 | 1 | <1 | <1 |
| Sr | 5000 | 2500 | 1500 | 1000 | 1500 | 600 | 2000 |
| Ti | | | | | | | |
| V | 400 | 150 | 300 | 250 | 80 | 250 | 300 |
| Y | 90 | 50 | 20 | 25 | <10 | 25 | 150 |
| Zn | 230 | 320 | 250 | 230 | 140 | 135 | 150 |
| Zr | 250 | 100 | 200 | 90 | 50 | 200 | 600 |
| La | 250 | 250 | 105 | 85 | <4 | 100 | 35 |
| Nd | <100 | 100 | 210 | 130 | <40 | 210 | 120 |
| Ce | 610 | 680 | 170 | 115 | <45 | 100 | <45 |
| Yb | 5 | | 2 | 2 | <1 | 3 | 15 |
| Eu | <100 | | 7 | 4 | <1 | 6 | 12 |
| Sm | | | <15 | <15 | <15 | <15 | <15 |
| Gd | | | <5 | <5 | <5 | <5 | 7 |
| Dy | | | <4 | <4 | <4 | <4 | 18 |
| Y | | | 24 | 25 | 8 | 25 | 140 |
| Sc | | | 16 | 12 | 90 | 20 | 1 |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Duplicate elements indicate different methods of analysis.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1266 | FS 1 290.2 | 1232 | ST 11 |
| 1245 | F 59C | 1235 | ST 26 |
| 1230 | ST 10A | 1236 | ST 34 |
| 1231 | ST 10D | | |

TABLE A-3. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | Ijolite (Unit 5c, 7b) |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1239 | 1240 | 1241 | 1243 | 1222 | 1223 | 1258 |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | <1 | | 930 |
| Ba | 550 | 1400 | 1800 | 520 | 400 | 100 | 6 |
| Be | 3 | 4 | 5 | 15 | <3 | 4 | |
| Bi | | | | | | | 9 |
| Co | 30 | 65 | 30 | 55 | 30 | 70 | 6 |
| Cr | <5 | 560 | 195 | 680 | 10 | 620 | 11 |
| Cu | 25 | 90 | 50 | 35 | 15 | 100 | 15 |
| Ga | 15 | 8 | 6 | 8 | 3 | 9 | |
| Hg | | | | | | | 13 |
| Li | 5 | 5 | 35 | 60 | <20 | 5 | |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <10 | <1 | <1 |
| Nb | 300 | 195 | 260 | 170 | 500 | 230 | 350 |
| Ni | 10 | 360 | 110 | 260 | 15 | 420 | <5 |
| Pb | 10 | <10 | 35 | 10 | <10 | <10 | 280 |
| Rb | 130 | 70 | 120 | 60 | 20 | 60 | 60 |
| Sb | | | | | <4 | | |
| Sc | <5 | 10 | 8 | 35 | <20 | 10 | 8 |
| Sn | <1 | <1 | <1 | <1 | <10 | <1 | 15 |
| Sr | 1000 | 800 | 2000 | 700 | 1500 | 800 | 3500 |
| Ti | | | | | | | |
| V | 200 | 200 | 150 | 100 | 100 | 250 | 500 |
| Y | 50 | 35 | 50 | 30 | 500 | 35 | 150 |
| Zn | 310 | 175 | 260 | 220 | 130 | 180 | 164 |
| Zr | 150 | 150 | 100 | 45 | 150 | 100 | 1500 |
| La | 165 | 240 | 295 | 70 | 400 | 180 | <100 |
| Nd | 200 | 360 | 380 | 250 | <300 | 250 | <100 |
| Ce | 200 | 420 | 480 | 185 | 1000 | 310 | 390 |
| Yb | 4 | 4 | 4 | 1 | | 4 | 15 |
| Eu | 8 | 10 | 12 | 6 | | 9 | <100 |
| Sm | <15 | 35 | 35 | 25 | | 30 | |
| Gd | <5 | <5 | 9 | <5 | | <5 | |
| Dy | 7 | 6 | 9 | <4 | | <4 | |
| Y | 55 | 35 | 50 | 6 | | 35 | |
| Sc | <1 | 14 | 11 | 25 | | | |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Duplicate elements indicate different methods of analysis.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1239 | ST 76 | 1222 | FS 2A 5 |
| 1240 | ST 81 | 1223 | FS 2C1 |
| 1241 | ST 84 | 1258 | FS 1 112.2 |
| 1243 | ST 97 | | |

**TABLE A-3. CONTINUED.**

| | Ijolite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1264** | **1265** | **1234** | **1237** | **1242** | **1268** | **1280** |
| Ag | <1 | <1 | <1 | 1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | |
| Ba | 1200 | 490 | 520 | 300 | 680 | 1640 | 1940 |
| Be | 15 | 9 | 6 | 6 | 15 | 3 | 10 |
| Bi | | | | | | | |
| Co | 32 | 19 | 30 | 30 | 25 | 22 | 19 |
| Cr | <5 | <5 | 5 | <5 | <5 | 5 | <5 |
| Cu | 48 | 34 | 50 | 45 | 50 | 50 | 28 |
| Ga | 15 | 20 | 15 | 15 | 15 | 30 | 15 |
| Hg | | | | | | | |
| Li | 8 | 7 | 5 | 5 | 6 | 10 | 21 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | 1 | <1 | <1 | <1 |
| Nb | 300 | 500 | 120 | 340 | 380 | 450 | 390 |
| Ni | <5 | <5 | <5 | 10 | <5 | <5 | <5 |
| Pb | 104 | 68 | 20 | 20 | 15 | <10 | <10 |
| Rb | 60 | 120 | 30 | 80 | 60 | 80 | 50 |
| Sb | | | | | | | |
| Sc | <5 | 5 | <5 | <5 | <5 | 5 | 2 |
| Sn | 4 | 7 | <1 | <1 | <1 | 5 | <3 |
| Sr | 3500 | 4000 | 1500 | 2500 | 1500 | 2000 | 3000 |
| Ti | | | | | | | |
| V | 300 | 600 | 100 | 250 | 200 | 450 | 500 |
| Y | 250 | 100 | 50 | 40 | 60 | 95 | 50 |
| Zn | 530 | 240 | 340 | 175 | 620 | 180 | 132 |
| Zr | 300 | 1000 | 100 | 100 | 45 | 1500 | 300 |
| La | 300 | 150 | 335 | 80 | 510 | 80 | 55 |
| Nd | 450 | <100 | 360 | 125 | 430 | 75 | 75 |
| Ce | 1040 | 570 | 480 | 75 | 730 | 160 | 95 |
| Yb | 15 | 10 | 2 | 3 | 4 | 8 | 5 |
| Eu | <100 | <100 | 12 | 4 | 13 | 4 | 2 |
| Sm | | | 22 | <15 | 45 | <15 | <15 |
| Gd | | | 6 | <5 | 5 | 5 | <5 |
| Dy | | | 10 | <4 | 10 | 11 | 6 |
| Y | | | 50 | 35 | 65 | | |
| Sc | | | 1 | <1 | 1 | | |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Duplicate elements indicate different methods of analysis.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1264 | FS 1 273.9 | 1242 | ST 86 |
| 1265 | FS 1 279.0 | 1268 | FS 2 157.8-158.2 |
| 1234 | ST 21 | 1280 | H5 21.95-22.45 |
| 1237 | ST 62 | | |

TABLE A-3. CONTINUED.

| | Ijolite (Unit 5c,7b) | | | | Rauhaugite (Unit 6a) | | Misc. |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1284 | 1290 | 1291 | 1263 | 1254 | 1227 | 1224 |
| Ag | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Au | | | | | | | |
| As | | | | | | | 50 |
| Ba | 2140 | 790 | 970 | 950 | 700 | 1300 | 1000 |
| Be | 8 | 5 | 10 | 10 | <1 | <3 | <3 |
| Bi | | | | | | | |
| Co | 32 | 24 | 30 | 33 | 20 | 20 | 80 |
| Cr | 5 | <5 | <5 | <5 | 15 | <10 | 30 |
| Cu | 50 | 19 | 83 | 54 | 8 | 7 | 270 |
| Ga | 25 | 25 | 20 | 15 | <1 | <5 | 20 |
| Hg | | | | | | | |
| Li | 11 | 6 | 6 | 7 | <3 | <20 | <20 |
| Mn | | | | | | | |
| Mo | <1 | <1 | <1 | <1 | <1 | <10 | <10 |
| Nb | 335 | 320 | 420 | 300 | 350 | 400 | <100 |
| Ni | 7 | <5 | <5 | <5 | 6 | 20 | 40 |
| Pb | <10 | <10 | <10 | 111 | 15 | <10 | 10 |
| Rb | 110 | 90 | 40 | 70 | <10 | <10 | |
| Sb | | | | | | | |
| Sc | 7 | 1 | <5 | <5 | 25 | 20 | 40 |
| Sn | <3 | <3 | <3 | 4 | 9 | <10 | <10 |
| Sr | 2500 | 3000 | 2500 | 3500 | 3500 | 2000 | 500 |
| Ti | | | | | | | |
| V | 450 | 250 | 300 | 250 | 40 | 80 | 250 |
| Y | 85 | 25 | 60 | 150 | 90 | 100 | 30 |
| Zn | 310 | 220 | 320 | 340 | 115 | 100 | 110 |
| Zr | 600 | 70 | 250 | 700 | 200 | 150 | 150 |
| La | 105 | 55 | 120 | 250 | 350 | <200 | |
| Nd | 95 | 60 | 150 | 400 | 400 | | |
| Ce | 225 | 120 | 250 | 810 | 710 | 1000 | |
| Yb | 6 | 2 | 3 | 8 | | | |
| Eu | 5 | 2 | 6 | <100 | | | |
| Sm | 19 | <15 | 22 | | | | |
| Gd | 6 | <5 | 7 | | | | |
| Dy | 10 | 4 | 8 | | | | |

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1284 | H5 153.0-153.6 | 1254 | F 236C |
| 1290 | H8 149.1-149.75 | 1227 | FS 9 |
| 1291 | H8 227.6-228.1 | 1224 | FS 2D1 |
| 1263 | FS 1 176.7 | | |

**TABLE A-4. NORMATIVE MINERALS (ALKALIC ROCKS) FOR WHOLE-ROCK SAMPLES FROM THE FIRESAND RIVER CARBONATITE COMPLEX.**

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1262** | **1244** | **1246** | **1247** | **1248** | **1249** | **1250** |
| QZ | 0.0 | 0.0 | 0.55 | 3.70 | 0.0 | 23.98 | 8.68 |
| CO | 0.18 | 0.0 | 0.0 | 0.0 | 0.0 | 0.38 | 0.0 |
| OR | 0.10 | 0.0 | 3.13 | 6.49 | 0.0 | 0.0 | 0.0 |
| AB | 0.0 | 0.0 | 1.83 | 0.0 | 0.56 | 1.11 | 2.93 |
| LC | 0.43 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| KAL | 0.0 | 0.67 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NEPH | 0.0 | 0.87 | 0.0 | 0.0 | 0.62 | 0.0 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.24 | 0.0 | 0.0 |
| NS | 0.0 | 0.29 | 0.23 | 1.64 | 0.90 | 0.0 | 0.09 |
| AC | 0.0 | 5.96 | 0.0 | 3.27 | 0.0 | 0.0 | 1.19 |
| TH | 1.33 | 0.31 | 0.22 | 0.22 | 0.09 | 0.09 | 0.09 |
| GEH | 5.82 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AKM | 0.0 | 2.37 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.92 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.WO | 0.0 | -2.72 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.EN | 0.0 | -1.74 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.FS | 0.0 | -0.80 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FO | 1.27 | 7.73 | 0.0 | 1.70 | 0.0 | 0.0 | 0.0 |
| FA | 1.52 | 3.95 | 5.75 | 6.10 | 1.66 | 1.21 | 1.28 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MT | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| SPH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RU | 0.0 | 0.20 | 0.22 | 0.25 | 0.0 | 0.0 | 0.03 |
| AP | 2.77 | 2.70 | 14.30 | 6.39 | 1.04 | 2.56 | 2.46 |
| CC | 86.80 | 77.21 | 64.99 | 63.92 | 92.40 | 67.01 | 78.87 |
| MGS | 0.0 | 0.99 | 4.56 | 4.72 | 0.75 | 0.44 | 0.79 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 0.57 | 0.37 | 0.31 | 0.39 | 0.37 | 0.41 | 0.43 |
| SUM | 100.78 | 99.29 | 96.10 | 98.78 | 98.63 | 97.19 | 96.84 |

QZ - Quartz; CO - Corundum; OR - Orthoclase; AB - Albite; LC - Leucite; KAL - Kalsilite; NEPH - Nepheline; CAR - Carnegieite; NS - $Na_2SiO_3$; AC - Acmite; TH - Thenardite; GEH - Gehlenite; AKM - Akermanite; FE-AK - Fe-Akermanite; D.WO - Wollastonite; D.EN - Enstatite; D.FS - Ferrosilite; FO - Forsterite; FA - Fayalite; ANDR - Andradite; HM - Hematite; MT - Magnetite; SPH - Sphene; PERV - Perovskite; RU - Rutile; AP - Apatite; CC - Calcite; MGS - Magnesite; FL - Fluorite; ZR - Zircon; BAD - Baddeleyite.

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1262 | FS1 166.1 | 1248 | F 148 |
| 1244 | F 59 | 1249 | F 176 |
| 1246 | F 72 | 1250 | F 179 |
| 1247 | F 112 | | |

TABLE A-4. CONTINUED.

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1251 | 1252 | 1253 | 1255 | 1256 | 1257 | 1228 |
| QZ | 0.0 | 8.59 | 0.11 | 0.87 | 3.24 | 0.36 | 18.15 |
| CO | 0.0 | 0.0 | 0.0 | 0.40 | 0.35 | 0.0 | 0.80 |
| OR | 5.98 | 6.55 | 0.41 | 0.06 | 8.91 | 1.59 | 20.48 |
| AB | 0.0 | 0.0 | 1.41 | 0.0 | 3.83 | 1.58 | 0.0 |
| LC | 2.93 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| KAL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NEPH | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.61 | 0.0 | 1.58 | 0.0 | 0.0 | 0.78 | 0.0 |
| AC | 1.56 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TH | 0.66 | 4.47 | 0.09 | 0.69 | 2.21 | 0.09 | 0.25 |
| GEH | 0.0 | 2.52 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.WO | 0.0 | 12.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.EN | 0.0 | 6.45 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.FS | 0.0 | 5.71 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FO | 0.57 | 5.12 | 0.29 | 0.0 | 7.51 | 0.0 | 0.0 |
| FA | 7.07 | 5.01 | 0.80 | 6.28 | 5.01 | 1.52 | 9.31 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 6.06 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MT | 0.0 | 0.0 | 0.0 | 0.09 | 4.76 | 0.0 | 3.20 |
| SPH | 0.0 | 0.64 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RU | 0.67 | 0.0 | 0.0 | 0.0 | 1.78 | 0.0 | 1.27 |
| AP | 4.17 | 0.05 | 0.0 | 0.14 | 2.13 | 13.44 | 2.30 |
| CC | 68.98 | 36.58 | 93.79 | 50.50 | 37.83 | 74.39 | 18.59 |
| MGS | 4.85 | 0.0 | 0.42 | 37.51 | 19.95 | 2.67 | 21.05 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 0.47 | 0.38 | 0.43 | 0.46 | 1.66 | 0.48 | 0.72 |
| SUM | 98.52 | 100.63 | 99.34 | 96.99 | 99.19 | 96.91 | 96.11 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1251 | F 185B | 1256 | F 341 |
| 1252 | F 195 | 1257 | F 344 |
| 1253 | F 208 | 1228 | ST-2A |
| 1255 | F 316 | | |

**TABLE A-4. CONTINUED.**

| | Sovite (Unit 5a,b,7a) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1229** | **1233** | **1238** | **1225** | **1226** | **1269** | **1274** |
| QZ | 0.0 | 0.92 | 0.0 | 0.0 | 0.0 | 0.63 | 4.49 |
| CO | 0.59 | 0.0 | 0.75 | 0.0 | 0.23 | 0.0 | 0.0 |
| OR | 0.0 | 1.00 | 0.65 | 0.0 | 0.0 | 11.51 | 3.48 |
| AB | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.91 | 2.22 |
| LC | 0.15 | 0.0 | 1.85 | 0.0 | 0.0 | 0.0 | 0.0 |
| KAL | 0.23 | 0.0 | 0.0 | 0.40 | 0.05 | 0.0 | 0.0 |
| NEPH | 0.0 | 0.0 | 0.0 | 0.0 | 0.32 | 0.0 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.45 |
| AC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.37 | 0.06 |
| TH | 0.07 | 0.73 | 0.11 | 0.18 | 0.04 | 0.89 | 0.71 |
| GEH | 0.0 | 1.66 | 0.0 | 1.53 | 0.0 | 0.0 | 0.0 |
| AKM | 0.0 | 0.0 | 0.0 | 3.95 | 0.0 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 1.66 | 0.26 | 0.0 | 0.0 |
| D.WO | 0.0 | 0.30 | 0.0 | -4.07 | -0.20 | 0.0 | 0.0 |
| D.EN | 0.0 | 0.18 | 0.0 | -2.55 | 0.0 | 0.0 | 0.0 |
| D.FS | 0.0 | 0.10 | 0.0 | -1.27 | -0.22 | 0.0 | 0.0 |
| FO | 0.85 | 5.08 | 0.67 | 5.81 | 0.0 | 6.14 | 0.0 |
| FA | 1.15 | 3.04 | 3.30 | 3.19 | 0.85 | 7.77 | 3.13 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 0.0 | 0.0 | 0.00 | 0.0 | 0.0 | 0.0 |
| MT | 0.28 | 3.27 | 1.60 | 7.47 | 0.0 | 1.17 | 0.0 |
| SPH | 0.0 | 0.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.17 | 0.0 | 0.0 | 0.0 |
| RU | 0.10 | 0.0 | 0.10 | 0.0 | 0.0 | 0.96 | 0.19 |
| AP | 1.42 | 5.11 | 5.02 | 3.55 | 0.07 | 9.80 | 8.78 |
| CC | 90.96 | 78.39 | 81.86 | 75.89 | 96.22 | 45.73 | 68.86 |
| MGS | 3.57 | 0.0 | 1.28 | 0.0 | 0.04 | 0.90 | 5.58 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 0.23 | 0.28 | 0.55 | 0.48 | 0.22 | 0.69 | 0.38 |
| SUM | 99.58 | 100.31 | 97.74 | 96.40 | 97.89 | 98.47 | 98.38 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1229 | ST-5 | 1226 | FS 7 |
| 1233 | ST-20 | 1269 | H2 191.2-191.7 |
| 1238 | ST-70 | 1274 | H2 290.5-291.15 |
| 1225 | FS 4B2 | | |

TABLE A-4. CONTINUED.

| | Sovite (Unit 5a,b,7a) | | | | Silicocarbonatite (Unit 5c,7b) | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1286 | 1287 | 1289 | 1259 | 1267 | 1270 | 1271 |
| QZ | 0.0 | 0.0 | 3.38 | 0.0 | 0.0 | 0.0 | 0.0 |
| CO | 0.0 | 0.0 | 1.17 | 0.0 | 0.0 | 0.0 | 0.0 |
| OR | 5.19 | 27.78 | 1.59 | 0.0 | 0.59 | 12.61 | 11.78 |
| AB | 0.08 | 6.10 | 0.0 | 0.0 | 0.0 | 0.0 | 9.42 |
| LC | 0.0 | 0.0 | 0.0 | 1.45 | 15.43 | 6.96 | 0.0 |
| KAL | 0.0 | 0.0 | 0.0 | 12.67 | 0.0 | 0.0 | 0.0 |
| NEPH | 0.13 | 12.82 | 0.0 | 0.0 | 0.06 | 0.0 | 3.76 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 0.0 | 0.0 | 0.0 | 1.24 | 0.0 | 0.0 |
| TH | 0.71 | 1.51 | 1.74 | 1.35 | 1.73 | 1.24 | 1.55 |
| GEH | 1.79 | 2.53 | 0.0 | 5.54 | 0.0 | 2.15 | 8.28 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.WO | 5.82 | 4.60 | 0.0 | 11.34 | 2.95 | 1.40 | 5.67 |
| D.EN | 3.63 | 2.52 | 0.0 | 6.98 | 1.93 | 0.98 | 3.70 |
| D.FS | 1.83 | 1.90 | 0.0 | 3.69 | 0.81 | 0.30 | 1.56 |
| FO | 6.66 | 10.49 | 0.0 | 9.74 | 18.79 | 15.57 | 10.78 |
| FA | 3.70 | 8.73 | 2.73 | 5.68 | 8.66 | 5.20 | 5.03 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.09 | 0.0 | 0.0 | 5.25 | 0.0 | 0.0 | 0.0 |
| MT | 3.45 | 4.29 | 0.10 | 0.0 | 5.35 | 7.29 | 9.20 |
| SPH | 1.47 | 2.33 | 0.0 | 3.16 | 8.68 | 6.35 | 10.87 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RU | 0.0 | 0.0 | 0.04 | 0.0 | 0.0 | 0.0 | 0.0 |
| AP | 15.50 | 0.66 | 5.07 | 8.36 | 0.07 | 6.94 | 3.15 |
| CC | 49.76 | 10.88 | 80.21 | 20.68 | 30.22 | 29.54 | 11.43 |
| MGS | 0.0 | 0.0 | 1.25 | 0.0 | 0.0 | 0.0 | 0.0 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 0.50 | 1.51 | 0.35 | 3.04 | 0.46 | 0.84 | 2.47 |
| SUM | 100.32 | 98.66 | 97.63 | 98.92 | 96.98 | 97.37 | 98.65 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1286 | H7 399.5-400.0 | 1267 | FS 2 42.1-42.25 |
| 1287 | H8 19.35-19.8 | 1270 | H2 213.8-214.2 |
| 1289 | H8 135.65-136.05 | 1271 | H2 227.7-228.4 |
| 1259 | FS 1 139.6 | | |

TABLE A-4. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1272** | **1273** | **1275** | **1277** | **1278** | **1279** | **1281** |
| QZ | 0.0 | 0.0 | 0.0 | 0.21 | 0.0 | 0.0 | 0.0 |
| CO | 0.0 | 0.0 | 0.21 | 0.0 | 0.0 | 0.0 | 0.0 |
| OR | 10.26 | 12.19 | 10.06 | 15.11 | 14.48 | 0.0 | 6.60 |
| AB | 11.85 | 1.84 | 0.0 | 0.75 | 0.0 | 0.0 | 0.0 |
| LC | 0.0 | 0.0 | 0.76 | 0.0 | 0.44 | 0.0 | 20.39 |
| KAL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.40 | 0.0 |
| NEPH | 5.59 | 8.87 | 0.13 | 0.0 | 0.0 | 0.0 | 1.81 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 2.73 | 0.0 | 0.0 | 0.0 | 0.0 | 2.12 |
| TH | 0.84 | 1.02 | 0.75 | 1.24 | 2.13 | 1.67 | 0.09 |
| GEH | 5.69 | 0.0 | 2.51 | 2.80 | 0.54 | 1.21 | 0.0 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.48 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.68 | 0.0 |
| D.WO | 0.07 | 0.0 | 0.0 | 1.92 | 5.19 | -4.83 | 0.0 |
| D.EN | 0.05 | 0.0 | 0.0 | 1.08 | 2.55 | -1.08 | 0.0 |
| D.FS | 0.02 | 0.0 | 0.0 | 0.76 | 2.55 | -4.06 | 0.0 |
| FO | 15.77 | 24.83 | 30.74 | 9.40 | 11.64 | 4.11 | 10.60 |
| FA | 6.98 | 8.80 | 7.67 | 7.31 | 12.84 | 17.06 | 12.50 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MT | 8.22 | 8.18 | 11.90 | 4.29 | 5.52 | 44.45 | 1.68 |
| SPH | 10.89 | 10.80 | 0.0 | 3.21 | 3.88 | 0.0 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.58 | 0.0 |
| RU | 0.0 | 0.07 | 2.92 | 0.0 | 0.0 | 2.00 | 1.08 |
| AP | 2.84 | 2.04 | 3.50 | 9.97 | 13.82 | 6.79 | 4.57 |
| CC | 16.47 | 15.47 | 23.40 | 38.63 | 22.95 | 24.54 | 33.09 |
| MGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.74 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 2.34 | 1.73 | 2.95 | 0.57 | 0.97 | 0.31 | 1.40 |
| SUM | 97.90 | 98.56 | 97.51 | 97.24 | 99.50 | 101.32 | 98.67 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1272 | H2 233.7-234.2 | 1278 | H4 18.9-19.4 |
| 1273 | H2 282.1-282.7 | 1279 | H4 162.7-163.2 |
| 1275 | H3 103.4-103.85 | 1281 | H5 65.1-65.65 |
| 1277 | H3 47.1-47.5 | | |

TABLE A-4. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1282 | 1283 | 1288 | 1292 | 1291B | 1260 | 1261 |
| QZ | 0.0 | 0.0 | 4.88 | 2.88 | 3.44 | 0.0 | 0.0 |
| CO | 0.0 | 0.0 | 0.50 | 0.92 | 0.48 | 0.0 | 0.0 |
| OR | 23.53 | 5.10 | 18.06 | 10.03 | 9.62 | 0.0 | 6.54 |
| AB | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LC | 3.68 | 17.01 | 0.0 | 0.0 | 0.0 | 0.0 | 6.62 |
| KAL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.55 | 0.0 |
| NEPH | 1.96 | 1.25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TH | 0.13 | 0.62 | 2.70 | 1.79 | 0.73 | 1.63 | 0.92 |
| GEH | 3.25 | 0.86 | 2.16 | 0.0 | 0.85 | 5.13 | 7.93 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.00 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.17 | 0.0 |
| D.WO | 0.86 | 2.81 | 0.0 | 0.0 | 0.0 | -0.37 | 7.41 |
| D.EN | 0.34 | 1.91 | 0.0 | 0.0 | 0.0 | -0.19 | 4.63 |
| D.FS | 0.53 | 0.67 | 0.0 | 0.0 | 0.0 | -0.17 | 2.33 |
| FO | 5.20 | 20.02 | 12.61 | 9.92 | 9.20 | 3.74 | 6.69 |
| FA | 8.88 | 7.75 | 4.80 | 3.92 | 6.03 | 3.56 | 3.72 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.71 |
| MT | 5.83 | 8.73 | 5.35 | 3.84 | 2.63 | 1.99 | 0.0 |
| SPH | 3.12 | 9.22 | 0.0 | 0.0 | 0.0 | 0.0 | 4.29 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.82 | 0.0 |
| RU | 0.0 | 0.0 | 1.96 | 0.53 | 0.56 | 0.0 | 0.0 |
| AP | 4.45 | 3.91 | 6.49 | 13.87 | 15.03 | 8.99 | 13.23 |
| CC | 33.06 | 17.97 | 38.17 | 50.43 | 50.44 | 66.35 | 23.86 |
| MGS | 0.0 | 0.0 | 0.0 | 0.39 | 0.0 | 0.0 | 0.0 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 1.10 | 0.42 | 1.66 | 1.32 | 0.65 | 0.90 | 1.85 |
| SUM | 96.71 | 98.26 | 99.34 | 99.83 | 99.68 | 100.09 | 97.74 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1282 | H5 69.3-69.75 | 1291B | H8 285.4-285.8 |
| 1283 | H5 105.9-106.5 | 1260 | FS 1 147 |
| 1288 | H8 62.75-63.2 | 1261 | FS 1 150.8 |
| 1292 | H8 298.0-298.55 | | |

TABLE A-4. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1266** | **1245** | **1230** | **1231** | **1232** | **1235** | **1236** |
| QZ | 4.66 | 0.0 | 0.0 | 0.0 | 7.36 | 0.0 | 11.64 |
| CO | 0.18 | 0.0 | 0.0 | 0.0 | 0.66 | 0.0 | 1.98 |
| OR | 21.84 | 4.40 | 1.44 | 0.18 | 13.46 | 0.0 | 22.19 |
| AB | 1.73 | 3.35 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LC | 0.0 | 0.0 | 15.89 | 16.42 | 0.0 | 5.90 | 0.0 |
| KAL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.42 | 0.0 |
| NEPH | 0.0 | 1.31 | 0.0 | 0.39 | 0.0 | 2.96 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 0.0 | 9.57 | 10.79 | 0.0 | 0.0 | 0.0 |
| TH | 2.30 | 0.31 | 0.22 | 0.66 | 1.31 | 1.42 | 4.95 |
| GEH | 0.0 | 6.11 | 0.0 | 0.0 | 0.0 | 2.69 | 0.52 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.WO | 0.0 | 19.32 | 0.0 | 0.0 | 0.0 | 5.13 | 0.0 |
| D.EN | 0.0 | 14.70 | 0.0 | 0.0 | 0.0 | 3.94 | 0.0 |
| D.FS | 0.0 | 2.58 | 0.0 | 0.0 | 0.0 | 0.64 | 0.0 |
| FO | 9.42 | 2.58 | 26.51 | 24.49 | 8.64 | 31.63 | 7.21 |
| FA | 8.62 | 0.44 | 8.66 | 10.45 | 7.80 | 5.69 | 0.83 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 9.62 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| MT | 4.24 | 0.0 | 4.71 | 4.40 | 4.24 | 13.32 | 12.09 |
| SPH | 0.0 | 5.03 | 0.0 | 0.54 | 0.0 | 13.07 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RU | 1.51 | 0.0 | 4.43 | 3.80 | 3.32 | 0.0 | 0.49 |
| AP | 7.88 | 2.18 | 0.92 | 1.33 | 0.26 | 2.27 | 1.16 |
| CC | 38.01 | 26.58 | 23.16 | 24.09 | 27.38 | 8.23 | 36.81 |
| MGS | 1.09 | 0.0 | 1.73 | 0.0 | 25.48 | 0.0 | 0.0 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 1.50 | 1.08 | 0.78 | 1.01 | 0.51 | 1.31 | 1.10 |
| SUM | 102.99 | 99.29 | 98.02 | 98.56 | 100.42 | 98.62 | 100.96 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1266 | FS 1 290.2 | 1232 | ST 11 |
| 1245 | F 59C | 1235 | ST 26 |
| 1230 | ST 10A | 1236 | ST 34 |
| 1231 | ST 10D | | |

TABLE A-4. CONTINUED.

| | Silicocarbonatite (Unit 5c,7b) | | | | | | Ijolite (Unit 5c, 7b) |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1239 | 1240 | 1241 | 1243 | 1222 | 1223 | 1258 |
| QZ | 0.0 | 0.0 | 0.0 | 1.58 | 0.0 | 0.0 | 3.19 |
| CO | 0.0 | 0.0 | 0.0 | 0.86 | 0.0 | 0.0 | 1.56 |
| OR | 0.0 | 4.20 | 16.52 | 24.44 | 0.0 | 9.62 | 14.81 |
| AB | 0.0 | 0.0 | 0.0 | 4.88 | 0.0 | 0.0 | 14.20 |
| LC | 9.66 | 10.58 | 3.71 | 0.0 | 0.0 | 3.65 | 0.0 |
| KAL | 4.61 | 0.0 | 0.0 | 0.0 | 1.24 | 0.0 | 0.0 |
| NEPH | 13.62 | 1.02 | 0.0 | 0.0 | 0.0 | 1.87 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 1.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TH | 2.57 | 1.77 | 3.09 | 0.44 | 0.37 | 2.52 | 0.66 |
| GEH | 6.44 | 0.0 | 2.43 | 0.0 | 23.75 | 0.48 | 21.65 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 11.28 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 4.23 | 0.0 | 0.0 |
| D.WO | 14.16 | 0.16 | 1.38 | 0.0 | -3.05 | 2.56 | 0.0 |
| D.EN | 6.53 | 0.13 | 0.82 | 0.0 | -1.96 | 2.06 | 0.0 |
| D.FS | 7.49 | 0.01 | 0.49 | 0.0 | -0.87 | 0.19 | 0.0 |
| FO | 3.17 | 22.66 | 10.89 | 10.18 | 14.36 | 22.52 | 4.62 |
| FA | 4.01 | 1.93 | 7.16 | 11.36 | 7.05 | 2.27 | 2.69 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 5.64 | 0.0 | 0.0 | 0.0 | 5.37 | 0.0 | 0.0 |
| MT | 0.0 | 15.54 | 5.27 | 5.38 | 0.0 | 15.11 | 8.16 |
| SPH | 6.16 | 12.58 | 0.98 | 0.0 | 0.0 | 13.32 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 1.38 | 0.0 | 0.0 |
| RU | 0.0 | 0.0 | 0.0 | 3.52 | 0.0 | 0.0 | 1.68 |
| AP | 4.50 | 2.37 | 5.25 | 0.76 | 1.63 | 1.30 | 0.88 |
| CC | 9.73 | 24.09 | 40.90 | 15.78 | 35.45 | 21.63 | 22.38 |
| MGS | 0.0 | 0.0 | 0.0 | 18.62 | 0.0 | 0.0 | 0.0 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 1.16 | 0.91 | 0.73 | 0.84 | 0.47 | 0.30 | 2.27 |
| SUM | 99.45 | 99.68 | 99.62 | 98.63 | 100.69 | 99.42 | 98.77 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1239 | ST 76 | 1222 | FS 2A 5 |
| 1240 | ST 81 | 1223 | FS 2C1 |
| 1241 | ST 84 | 1258 | FS 1 112.2 |
| 1243 | ST 97 | | |

**TABLE A-4. CONTINUED.**

| | Ijolite (Unit 5c,7b) | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ref. No.** | **1264** | **1265** | **1234** | **1237** | **1242** | **1268** | **1280** |
| QZ | 0.0 | 13.34 | 0.0 | 8.04 | 0.0 | 8.12 | 10.63 |
| CO | 0.0 | 0.49 | 0.0 | 0.65 | 0.0 | 0.0 | 1.01 |
| OR | 8.80 | 15.88 | 0.0 | 20.54 | 3.98 | 23.20 | 22.25 |
| AB | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| LC | 5.32 | 0.0 | 0.0 | 0.0 | 5.77 | 0.0 | 0.0 |
| KAL | 0.0 | 0.0 | 2.41 | 0.0 | 0.0 | 0.0 | 0.0 |
| NEPH | 1.85 | 0.0 | 1.37 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TH | 2.30 | 5.54 | 1.20 | 8.66 | 4.17 | 2.98 | 1.83 |
| GEH | 12.43 | 15.38 | 7.77 | 16.61 | 12.58 | 16.52 | 11.96 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.WO | 11.93 | 0.0 | 23.48 | 0.0 | 17.06 | 0.0 | 0.0 |
| D.EN | 6.51 | 0.0 | 15.53 | 0.0 | 8.40 | 0.0 | 0.0 |
| D.FS | 4.98 | 0.0 | 6.22 | 0.0 | 8.33 | 0.0 | 0.0 |
| FO | 4.39 | 5.73 | 0.0 | 7.54 | 1.57 | 6.58 | 7.42 |
| FA | 3.71 | 8.19 | 0.0 | 9.69 | 1.72 | 5.81 | 6.87 |
| ANDR | 0.0 | 0.0 | 1.09 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 6.66 | 0.0 | 8.70 | 0.0 | 9 60 | 0.0 | 0.0 |
| MT | 0.0 | 7.54 | 0.0 | 5.13 | 0.0 | 8.08 | 3.97 |
| SPH | 5.35 | 0.0 | 2.62 | 0.0 | 4.00 | 3.14 | 0.0 |
| PERV | 0.0 | 0.0 | 3.58 | 0.0 | 0.0 | 0.0 | 0.0 |
| RU | 0.0 | 1.92 | 0.0 | 1.86 | 0.0 | 0.17 | 0.95 |
| AP | 4.66 | 4.17 | 8.76 | 4.50 | 6.63 | 4.50 | 0.19 |
| CC | 19.65 | 21.02 | 14.81 | 18.54 | 16.00 | 17.54 | 28.18 |
| MGS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 2.20 | 2.40 | 1.63 | 0.57 | 1.49 | 1.89 | 1.83 |
| SUM | 100.75 | 101.60 | 99.17 | 102.33 | 101.29 | 98.53 | 97.07 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1264 | FS 1 273.9 | 1242 | ST 86 |
| 1265 | FS 1 279.0 | 1268 | FS 2 157.8-158.2 |
| 1234 | ST 21 | 1280 | H5 21.95-22.45 |
| 1237 | ST 62 | | |

TABLE A-4. CONTINUED.

| | Ijolite (Unit 5c,7b) | | | | Rauhaugite (Unit 6a) | | Misc. |
|---|---|---|---|---|---|---|---|
| Ref. No. | 1284 | 1290 | 1291 | 1263 | 1254 | 1227 | 1224 |
| QZ | 3.12 | 0.0 | 0.0 | 6.83 | 0.0 | 0.0 | 19.07 |
| CO | 0.45 | 0.0 | 0.0 | 0.79 | 0.02 | 8.04 | 1.07 |
| OR | 30.22 | 24.76 | 6.32 | 17.71 | 0.0 | 0.0 | 3.72 |
| AB | 0.0 | 3.02 | 0.0 | 0.0 | 1.59 | 0.0 | 15.73 |
| LC | 0.0 | 0.0 | 3.76 | 0.0 | 0.0 | 0.0 | 0.0 |
| KAL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.13 | 0.0 |
| NEPH | 0.0 | 9.25 | 4.81 | 0.0 | 0.0 | 0.0 | 0.0 |
| CAR | 0.0 | 0.0 | 0.0 | 0.0 | 0.99 | 0.0 | 0.0 |
| NS | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| AC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| TH | 1.54 | 0.62 | 2.35 | 2.89 | 0.22 | 0.18 | 2.04 |
| GEH | 12.13 | 3.23 | 7.56 | 10.31 | 0.0 | 0.0 | 23.07 |
| AKM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.30 | 0.0 |
| FE-AK | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D.WO | 0.0 | 0.92 | 13.77 | 0.0 | 0.0 | -9.60 | 0.0 |
| D.EN | 0.0 | 0.45 | 7.25 | 0.0 | 0.0 | -8.28 | 0.0 |
| D.FS | 0.0 | 0.46 | 6.10 | 0.0 | 0.0 | 0.0 | 0.0 |
| FO | 10.94 | 7.59 | 4.60 | 8.35 | 0.0 | 12.40 | 9.53 |
| FA | 8.55 | 8.50 | 4.28 | 7.24 | 0.0 | 0.0 | 13.31 |
| ANDR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| HM | 0.0 | 0.0 | 6.36 | 0.0 | 0.54 | 0.33 | 0.0 |
| MT | 6.39 | 4.15 | 0.0 | 6.83 | 12.87 | 13.07 | 3.78 |
| SPH | 0.0 | 3.70 | 5.20 | 0.0 | 0.0 | 0.0 | 0.0 |
| PERV | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RU | 2.14 | 0.0 | 0.0 | 1.94 | 0.06 | 0.0 | 0.74 |
| AP | 5.82 | 1.56 | 7.15 | 9.40 | 15.72 | 2.49 | 0.43 |
| CC | 17.29 | 28.18 | 19.40 | 23.63 | 38.26 | 54.60 | 6.63 |
| MGS | 0.0 | 0.0 | 0.0 | 0.0 | 26.26 | 14.64 | 0.0 |
| FL | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ZR | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| BAD | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $H_2O$ | 1.52 | 1.60 | 1.38 | 2.01 | 0.55 | 0.28 | 1.00 |
| SUM | 100.11 | 97.99 | 100.28 | 97.92 | 97.07 | 99.59 | 100.11 |

Note: For sample descriptions, see Table A-1. Alkalic norms were calculated using the method of LeBas (1973).

| Ref. No. | Sample No. | Ref. No. | Sample No. |
|---|---|---|---|
| 1284 | H5 153.0-153.6 | 1254 | F 236C |
| 1290 | H8 149.1-149.75 | 1227 | FS 9 |
| 1291 | H8 227.6-228.1 | 1224 | FS 2D1 |
| 1263 | FS 1 176.7 | | |

**TABLE A-5. AVERAGE CHEMICAL COMPOSITIONS* (WEIGHT PERCENT AND PPM) OF LITHOLOGIC UNITS FOR THE FIRESAND RIVER CARBONATITE COMPLEX.**

| | Sovite Unit 5a,b,7a (N = 27) | | Silicocarbonatite & Ijolite - Unit 5c,7b (N = 44) | | Rauhaugite Unit 6a (N = 2) | |
|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Mean | Std. Deviation | Mean | Std. Deviation |
| $SiO_2$ | 13.51 | 11.07 | 26.18 | 5.65 | 0.95 | 0.78 |
| $Al_2O_3$ | 1.72 | 2.25 | 5.83 | 2.60 | 4.38 | 5.23 |
| $Fe_2O_3$ | 1.27 | 1.67 | 5.25 | 2.58 | 9.36 | 0.05 |
| FeO | 2.91 | 2.16 | 6.76 | 3.25 | 3.49 | 0.07 |
| MgO | 3.62 | 4.29 | 8.31 | 4.71 | 12.57 | 0.11 |
| CaO | 41.47 | 12.06 | 22.86 | 7.29 | 31.10 | 1.27 |
| $Na_2O$ | 0.78 | 0.75 | 1.25 | 0.82 | 0.29 | 0.30 |
| $K_2O$ | 0.84 | 1.28 | 2.96 | 1.30 | 0.02 | 0.03 |
| $TiO_2$ | 0.31 | 0.45 | 2.44 | 1.36 | 0.03 | 0.04 |
| $P_2O_5$ | 2.01 | 1.93 | 2.13 | 1.67 | 3.84 | 3.95 |
| MnO | 0.31 | 0.19 | 0.42 | 0.15 | 0.22 | 0.30 |
| $CO_2$ | 32.75 | 9.15 | 11.98 | 4.97 | 32.00 | 0.42 |
| S | 0.16 | 0.19 | 0.41 | 0.43 | 0.05 | 0.05 |
| $H_2O+$ | 0.14 | 0.24 | 0.98 | 0.56 | 0.12 | 0.17 |
| $H_2O-$ | 0.39 | 0.26 | 0.43 | 0.25 | 0.30 | 0.36 |
| LOI | 5.15 | 10.70 | 6.11 | 7.16 | 0.00 | 0.00 |
| TOTAL | 99.23 | 0.75 | 98.57 | 1.14 | 99.05 | 0.78 |
| S.G. | 0.64 | 1.21 | 1.46 | 1.55 | 1.47 | 2.08 |
| Ag | <1.00 | 0.00 | <0.95 | 0.30 | <1.00 | 0.00 |
| As | | | <1.00 | 0.00 | | |
| Ba | 596.30 | 270.39 | 1058.86 | 668.23 | 1000.00 | 424.26 |
| Co | 9.07 | 18.09 | 36.20 | 17.89 | 20.00 | 0.00 |
| Cr | 55.48 | 140.72 | 172.59 | 274.83 | 2.50 | 17.68 |
| Cu | 34.85 | 48.61 | 63.11 | 41.27 | 7.50 | 0.71 |
| Li | 4.00 | 8.30 | 9.16 | 12.27 | <11.50 | 12.02 |
| Ni | 35.30 | 120.04 | 113.25 | 184.59 | 13.00 | 9.90 |
| Pb | 11.89 | 15.44 | 17.55 | 50.31 | 2.50 | 17.68 |
| Sb | | | <4.00 | 0.00 | | |
| Zn | 76.89 | 74.97 | 252.89 | 144.11 | 107.50 | 10.61 |
| Be | 1.68 | 4.06 | 7.18 | 4.48 | <2.00 | 1.41 |
| Mo | <1.35 | 1.77 | <0.98 | 1.86 | <5.50 | 6.36 |
| Sc | 2.40 | 10.83 | 8.48 | 14.19 | 22.50 | 3.54 |
| V | 158.40 | 150.32 | 313.22 | 198.24 | 60.00 | 28.28 |
| Y | 73.84 | 79.22 | 71.73 | 81.72 | 95.00 | 7.07 |
| Ga | 2.68 | 4.16 | 14.45 | 6.75 | <3.00 | 2.83 |
| Nb | 311.24 | 518.93 | 391.41 | 378.45 | 375.00 | 35.36 |
| Rb | 15.38 | 31.14 | 70.70 | 34.94 | <10.00 | 0.00 |
| Sr | 3776.33 | 3092.49 | 2711.36 | 1534.29 | 2750.00 | 1060.66 |
| Zr | 192.60 | 214.93 | 410.00 | 412.70 | 175.00 | 35.36 |
| Sn | <2.88 | 1.69 | 0.23 | 4.45 | <0.50 | 13.44 |
| Sm | <11.82 | 10.55 | 6.32 | 21.07 | | |
| Eu | <12.69 | 38.96 | <14.71 | 41.99 | | |
| Gd | 1.91 | 7.38 | 0.00 | 6.16 | | |
| Dy | <1.09 | 5.09 | 3.68 | 6.39 | | |
| Yb | 1.38 | 1.98 | 4.79 | 3.82 | | |
| Ce | 281.67 | 416.42 | 339.88 | 277.62 | 855.00 | 205.06 |
| La | 199.24 | 211.15 | 159.21 | 123.68 | 75.00 | 388.91 |
| Nd | 145.42 | 166.07 | 151.98 | 146.92 | 400.00 | 0.00 |
| Y | 34.80 | 28.38 | 42.54 | 34.07 | | |
| Sc | 7.50 | 10.50 | 15.75 | 24.99 | | |

Note: Duplicate elements indicate different methods of analysis.

*The average compositions may include duplicate samples or analyses which are not listed in Tables A-2 to A-4.

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# Index


## A

Aeromagnetic data, 31
  Linear trends, 30
  Map, 8

Algoma Steel Co. Ltd., 33
  Drilling, 33
  Property description, 33—34

Alkalic rock - carbonatite magmatism, 29

Alteration
  Mineral, 30
  Silicocarbonatite to ijolite, 23
  Sovite, 15

Amphibole
  Fractures, 29
    Intermediate to felsic metavolcanics, 10
  Silicocarbonatite to ijolite, 21
    Microprobe analyses, 22
  Sovite, 15

Analcite, Silicocarbonatite to ijolite, 23

Analyses
  Average chemical compositions
    Ijolite, 76
    Rauhaugite, 76
    Silicocarbonatite, 76
    Sovite, 76
  Major element
    Ijolite, 54—55
    Metavolcanic, Fenitized mafic, 55
    Rauhaugite, 55
    Silicocarbonatite, 52—54
    Sovite, 51—52
  Microprobe
    Amphibole, Silicocarbonatite to ijolite, 22
    Carbonates, 15
    Garnet, Sovite, 17
    Iron-titanium oxides, Sovite, 14
    Mica, Silicocarbonatite to ijolite, 20
    Monticellite, Sovite, 16
    Olivine, Sovite, 16
    Pyroxene, Silicocarbonatite to ijolite, 19
  Normative minerals
    Ijolite, 73—75
    Metavolcanic, Fenitized mafic, 75
    Rauhaugite, 75
    Silicocarbonatite, 69—73
    Sovite, 66—69
  Trace element
    Ijolite, 63—65
    Metavolcanic, Fenitized mafic, 65
    Rauhaugite, 65
    Silicocarbonatite, 59—63
    Sovite, 56—59

Ankerite, Carbonatite, Microprobe analyses, 15

Apatite, 33, 36
  Ferruginous dolomite, 26
  Ijolite, 24
  Silicocarbonatite to ijolite, 17
  Sovite, 13

Archean, Petrology, 9—12

## B

Banding
  Carbonatite, 9
  Carbonatite dikes, 31
  Intermediate to felsic metavolcanic flows, 9
  Silicocarbonatite dike, 27
  Sovite, 13

Barite, 33
  Dolomite-rich core, 9
  Miarolitic cavities, 31

Barite-quartz phase, Petrology, 26—27

Biotite
  Fractures, 29
    Intermediate to mafic metavolcanics, 9
  Ijolite, 24
  Lamprophyre dike, 28
  Metavolcanic xenolith, 24
  Silicocarbonatite to ijolite, 18—19
  Sovite, 14

Biotite-phlogopite
  Ijolite, 24
  Sovite, 14

Biotitite, Petrology, 25

Brecciation, Intermediate to felsic metavolcanics, 10

## C

Calcite, 33
  Algoma Steel, 34
  Carbonatite, Microprobe analyses, 15
  Flux, 36
  Fractures, 29
  Sovite, 13—14

Calcite border, Magnetic response, 31

Carbonate
  Ferruginous, Petrology, 28
  Ferruginous carbonate, 28
  Ferruginous dolomite, 26
  Fractures
    Ferruginous, Intermediate to felsic metavolcanics, 10
    White, Intermediate to mafic metavolcanics, 9
  Ijolite, 25
  Lamprophyre dike, 28
  Miarolitic cavities, 31
  Rhombs, Sovite, 13
  Silicocarbonatite to ijolite, 18

Sovite, 13—14

Carbonatite - alkalic rock complexes, Map, 4

Carbonatite diking, 8

Carbonatite-lamprophyre dikes, 8

Chlorite, Silicocarbonatite to ijolite, 23

Clinopyroxene
Ijolite, 25
Lamprophyre dike, 28
Quartz-feldspar porphyry, 12
Silicocarbonatite to ijolite, 17—18
Sovite, 13

Core rocks, Dolomite-rich (rauhaugite), 9
Petrology, 25—27

## D

Diabase dikes, Petrology, 12

Dike rocks
Carbonatitic, 27—28
Diabase, Petrology, 12
Petrology, 27—28

Dolomite, 26
Carbonatite, Microprobe analyses, 15
Ferruginous
Carbonatite, Microprobe analyses, 15
Petrology, 25—26

Dolomite core
Magnetic response, 31
Rare earths, 36

Dolomite-rich, Carbonatite complex, 9

Drilling, Table, 33

## E

Early Precambrian, Petrology, 9—12

Economic geology, 33—36

Emplacement
Barite-quartz phase, 27
Silicocarbonatite dikes, 27
Silicocarbonatite to ijolite, 17, 21

## F

Faulting, Horst structure, 30

Feldspar
Ijolite, 25
Intermediate to felsic metavolcanics, 10
Quartz-feldspar porphyry, 11, 12

Feldspar porphyry, 10

Fenitization, 8, 30
Intermediate to felsic metavolcanics, 10
Intermediate to mafic metavolcanics, 9
Quartz-feldspar porphyry, 10—11

Firesand River carbonatite complex, Petrology, 12—28

Firesand River Fault, 31

Fractures
Amphibole/pyroxene, 29
Biotite/calcite, 29
Intermediate to felsic metavolcanics, 10
Intermediate to mafic metavolcanics, 9
Quartz-feldspar porphyry, 11

Fragments, Oligomictic tuff, 9—10

## G

Garnet
Ijolite, 24
Lamprophyre dike, 28
Silicocarbonatite to ijolite, 23
Sovite, 16
Microprobe analyses, 17

Gibson Property
Drilling, 33
Property description, 34

Greenschist facies, Middle, 29

## H

Hawk Lake Fault, 30

Hematite
Ferruginous dolomite, 25
Gibson Property, 34
Iron, 36

Hematite and/or goethite, Dolomite-rich core, 9

Horst structure, 30

## I

Ijolite
Analyses
Average chemical compositions, 76
Major element, 54—55
Normative minerals, 73—75
Trace element, 63—65
Nomenclature, 5—6
Petrology, 24—25, 39, 40, 41, 44, 45, 46, 48, 49, 50

Ilmenite, Sovite, Microprobe analyses, 14

International Minerals and Chemical Co., 33
Drilling, 33
Property description, 35

Intrusive rocks, Felsic, Petrology, 10—12

Iron
Carbonatite rim, 9
Ferruginous dolomite, 26

Iron assays, Table, Gibson Property, 35

Iron oxide, Ferruginous dolomite, 25

Iron-titanium oxides, Sovite, Microprobe analyses, 14

## K

Kapuskasing Subprovince, Faulting, 30

## L


Lamprophyre dikes, Petrology, 27—28

Lamprophyre-carbonatite dikes, 29

Late Precambrian, Petrology, 12—28

Layering, Carbonatite, 31

Lime, Algoma Steel, 34

Lithologic units, Table, 7


## M


Magnesio-arfvedsonite, Silicocarbonatite to ijolite, 21
  Microprobe analyses, 22

Magnetic data, 31

Magnetite
  Ijolite, 24
  Lamprophyre dike, 28
  Silicocarbonatite to ijolite, 18
  Sovite, 13
    Microprobe analyses, 14

Malignite, Nomenclature, 6

Manitowik Lake Fault, 30

Metamorphism, 29—30

Metasomatizing fluids, 29—30

Metavolcanics
  Fenitized mafic
    Analyses
      Major element, 55
      Normative minerals, 75
      Trace element, 65
    Petrology, 37
  Intermediate to felsic, Petrology, 9—10
  Intermediate to mafic, Petrology, 9
  Petrology, 9—10

Miarolitic cavities, 8, 26
  Carbonatite, 31
  Quartz, Sovite, 16

Mica
  Silicocarbonatite to ijolite, 18—19
    Microprobe analyses, 20
  Sovite, 14
  Zoning, 30

Monticellite, Sovite, Microprobe analyses, 16

Morrison et al. Claims, Property description, 35—36


## N


Nepheline
  Ijolite, 24
  Silicocarbonatite to ijolite, 23

Niobium, 7, 31, 33, 36
  Algoma Steel, 33, 34
  Morrison et al. Claims, 36


## O


Olivine
  Silicocarbonatite to ijolite, 23
  Sovite, 15—16
    Microprobe analyses, 16


## P


Pango Gold Mines Ltd., Property description, 36

Perovskite, Silicocarbonatite to ijolite, 23

Perthite, Quartz-feldspar porphyry, 11—12

Petrology, 28—29

Phlogopite, Silicocarbonatite to ijolite, 18—19

Phosphorous, International Minerals & Chemical Co., 35

Phosphorus, 7

Plagioclase
  *See also* Feldspar
  Ferruginous carbonate, 28
  Quartz-feldspar porphyry, 11
  Silicocarbonatite to ijolite, 23

Proterozoic, Petrology, 12—28

Pyrite, 26
  Ferruginous carbonate, 28

Pyrochlore, Morrison et al. Claims, 36
  Map, 35

Pyroxene
  Fractures, 29
    Intermediate to felsic metavolcanics, 10
  Intermediate to felsic metavolcanics, 10
  Metavolcanic xenolith, 24
  Quartz-feldspar porphyry, 12
  Silicocarbonatite to ijolite, Microprobe analyses, 19

Pyrrhotite, Sovite, 16


## Q


Quartz
  Barite-quartz phase, 26
  Dolomite-rich core, 9
  Ferruginous carbonate, 28
  Intermediate to felsic metavolcanics, 10
  Miarolitic cavities, 31
  Quartz-feldspar porphyry, 11
  Sovite, 16

Quartz-feldspar porphyry, 10
  Petrology, 10—12


## R


Radioactivity, 31

Rare earths, 36

Rauhaugite
  Analyses
    Average chemical compositions, 76
    Major element, 55

Normative minerals, 75
Trace element, 65
Core, 9, 32
Petrology, 38, 44

Recommendations
Future study, 31—32
Prospector, 36

Richterite, Silicocarbonatite to ijolite, 21
Microprobe analyses, 22

Rim rocks
Calcite flux, 36
Petrology, 12—25

Rims
Biotite, Ijolite, 24
Calcite-rich, Carbonatite complex, 8
Clinopyroxene, Silicocarbonatite to ijolite, 17
Feldspar, Quartz-feldspar porphyry, 11
Garnet, Ijolite, 24
Metavolcanic xenolith, 23
Mica
Silicocarbonatite to ijolite, 18
Sovite, 14
Olivine, Sovite, 16
Quartz-feldspar porphyry, 11
Reaction, Fragments, Oligomictic tuff, 10

Ring dikes, Carbonatite, 31

## S

Sericite, Quartz-feldspar porphyry, 12

Silicocarbonatite
Analyses
Average chemical compositions, 76
Major element, 52—54
Normative minerals, 69—73
Trace element, 59—63
Nomenclature, 6
Petrology, 37, 38, 39, 40, 41, 42, 45, 46, 47, 48, 49, 50

Silicocarbonatite dikes
Intermediate to mafic metavolcanics, 9
Petrology, 27

Silicocarbonatite to ijolite
Microprobe analyses
Amphibole, 22
Mica, 20
Pyroxene, 19
Petrology, 17—24

Sovite
Analyses
Average chemical compositions, 76
Major element, 51—52
Normative minerals, 66—69
Trace element, 56—59
Ferruginous, Petrology, 16—17
Microprobe analyses
Garnet, 17
Iron-titanium oxides, 14
Olivine and monticellite, 16
Nomenclature, 6
Petrology, 12—16, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 49

Sovite dikes, Petrology, 27

Sphene
Ijolite, 25
Silicocarbonatite to ijolite, 23

Structural geology, 30—31

Syenite, Nomenclature, 6

## T

Thorium, 31, 36

Tuffs, Oligomictic, 9—10

## U

Uranium, 7, 31, 33, 36

## W

Wall rock fragments, 8

Wawa Lake Fault, 30

Wawa Subprovince, 30

Weathering, Differential, Feldspar, Quartz-feldspar porphyry, 11

## X

Xenolith, Metavolcanic, Petrology, 23

## Z

Zeolite, 30
Silicocarbonatite to ijolite, 23

Zircon
Ijolite, 25
Silicocarbonatite to ijolite, 23

Zoning, Micas, 30
*See also* Rims

Normative minerals, 75
Trace element, 65
Core, 9, 32
Petrology, 38, 44
Recommendations
Future study, 31—32
Prospector, 36
Richterite, Silicocarbonatite to ijolite, 21
Microprobe analyses, 22
Rim rocks
Calcite flux, 36
Petrology, 12—25
Rims
Biotite, Ijolite, 24
Calcite-rich, Carbonatite complex, 8
Clinopyroxene, Silicocarbonatite to ijolite, 17
Feldspar, Quartz-feldspar porphyry, 11
Garnet, Ijolite, 24
Metavolcanic xenolith, 23
Mica
Silicocarbonatite to ijolite, 18
Sovite, 14
Olivine, Sovite, 16
Quartz-feldspar porphyry, 11
Reaction, Fragments, Oligomictic tuff, 10
Ring dikes, Carbonatite, 31

## S

Sericite, Quartz-feldspar porphyry, 12
Silicocarbonatite
Analyses
Average chemical compositions, 76
Major element, 52—54
Normative minerals, 69—73
Trace element, 59—63
Nomenclature, 6
Petrology, 37, 38, 39, 40, 41, 42, 45, 46, 47, 48, 49, 50
Silicocarbonatite dikes
Intermediate to mafic metavolcanics, 9
Petrology, 27
Silicocarbonatite to ijolite
Microprobe analyses
Amphibole, 22
Mica, 20
Pyroxene, 19
Petrology, 17—24
Sovite
Analyses
Average chemical compositions, 76
Major element, 51—52
Normative minerals, 66—69
Trace element, 56—59
Ferruginous, Petrology, 16—17
Microprobe analyses
Garnet, 17
Iron-titanium oxides, 14
Olivine and monticellite, 16
Nomenclature, 6
Petrology, 12—16, 37, 38, 39, 40, 42, 43, 44, 45, 46, 47, 49
Sovite dikes, Petrology, 27
Sphene
Ijolite, 25
Silicocarbonatite to ijolite, 23
Structural geology, 30—31
Syenite, Nomenclature, 6

## T

Thorium, 31, 36
Tuffs, Oligomictic, 9—10

## U

Uranium, 7, 31, 33, 36

## W

Wall rock fragments, 8
Wawa Lake Fault, 30
Wawa Subprovince, 30
Weathering, Differential, Feldspar, Quartz-feldspar porphyry, 11

## X

Xenolith, Metavolcanic, Petrology, 23

## Z

Zeolite, 30
Silicocarbonatite to ijolite, 23
Zircon
Ijolite, 25
Silicocarbonatite to ijolite, 23
Zoning, Micas, 30
*See also* Rims

MAPS
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CARTES
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